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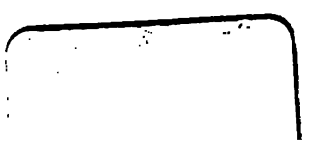

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TEST OF THE NEW YORK HYGEIA ICE-MAKING PLANT.*

BY A. G. HUPFEL, '93, H. E. GRISWOLD, '93, AND WILLIAM P. MACKENZIE, '93.

THE investigation was made upon the plant of the Hygeia Ice Company, situated at the foot of East Fifty-second Street, New York City.

The ammonia compressors and attachments were constructed by the De La Vergne Refrigerating Machine Company.

There were three compressor engines, each operating two double-acting ammonia compressors. Two of the machines are rated at 60 tons ice-making capacity each, and the third 90 tons, giving a total ice-making capacity of 210 tons per day.

Preparations for testing were commenced April 1. A two days' test of the boiler was made on April 4 and 5. Tests were then made of the agitator engine which is used to circulate the

* This test was made and reported on as a Graduation Thesis. A brief abstract of the same was presented at the meeting of the Mechanical Section of the American Association for the Advancement of Science at Madison, Wis., and has been published in the *American Machinist* of January 11, 1894.

brine in the freezing tanks. Weighings were made of a number of cakes of ice from the six tanks, in order to obtain the average weight per cake and the loss due to sprinkling hot water on the cans to remove the ice from them.

On May 1 preparations were completed for a continuous test of the entire plant for one week. Indicator rigging was attached, revolution counters placed on the engines and pumps, and an attachment made for obtaining the mean position of the valve which controls the supply of live steam to the condenser.

To obtain the drip water of condensation in the exhaust pipes, oil separators, and that from the engines and pumps, the waste pipe was connected to a hose and the water measured off in barrels.

The positions of all valves, a record of which might be of use in subsequent tests, were noted at regular intervals during the continuous test of one week.

The plant was run for about 12 hours per day because the demand at the season of the year at which the test was made could be met without pushing the plant to its utmost capacity.

The reboiler, pumps, etc., were tested in the evening of May 9. Independent tests were made upon the reboiler, sprinkler, jet blowers, and " Schaefer's " pump upon subsequent days.

The general arrangement of a portion of the plant is shown in Fig. 1.

The water which finally leaves the condenser A is the accumulation of the exhausts from the various pumps and engines, together with an amount of live steam injected into it directly from the boilers. This last quantity is used to make up any deficit in the amount of water necessary to supply the ice cans. This water on leaving the condensers is violently reboiled at B, and afterwards cooled by running through a coil surface cooler C. It then passes through an oil separator D, after which it runs through three charcoal filters, and deodorizers E, placed in series and containing 28

feet of charcoal. It next passes into the supply tank G, in which there is an electrical attachment for detecting salt. Nitrate of

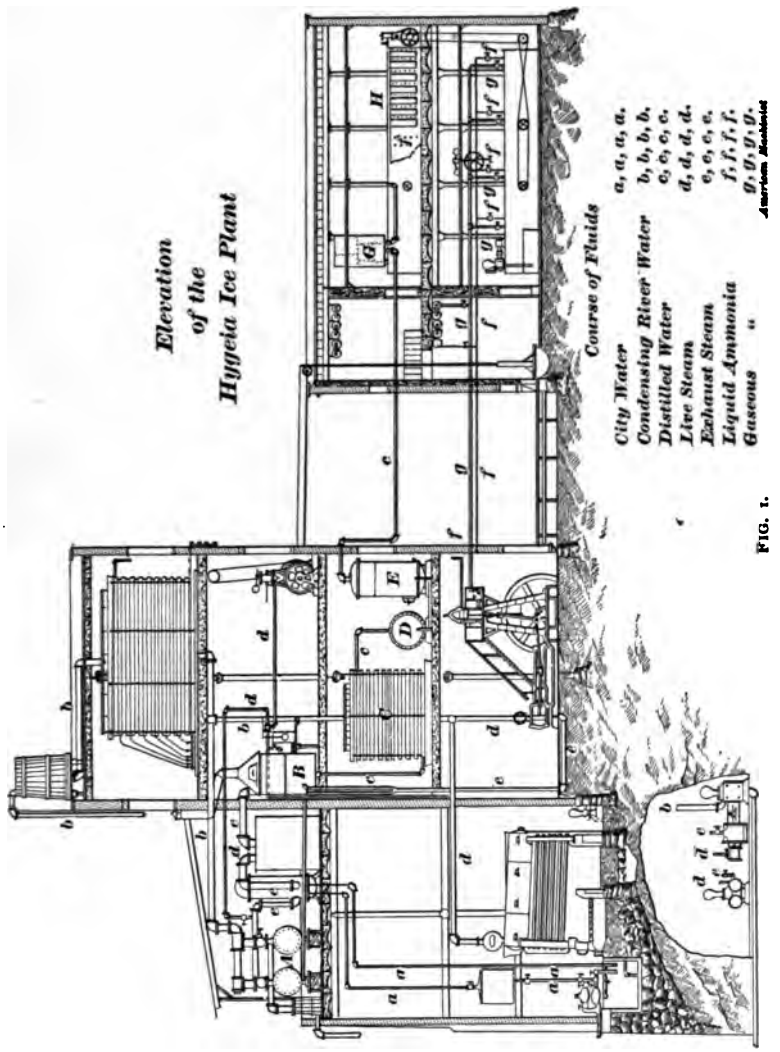

FIG. 1.

silver tests are also made for salt daily. From this tank it is fed to the ice cans H, which are carefully covered so that the water con-

tained cannot possibly receive any impurities. The ice was perfectly clear and the edges of the cakes sharp. There was but a thin core of air bubbles through the center of each cake. No odor or taste could be observed at the center of the cake, which is a crucial test for the quality of artificial ice, and shows that the method employed to produce pure ice in this plant was a most perfect one.

The final results of the tests were as follows:

Net ice made per pound of coal in pounds	7.12
Pounds of net ice per hour per horse-power	37.8
Net ice manufactured per day (12 hours) in tons	97
Average pressure of ammonia gas at condenser in pounds per square inch above the atmosphere	135.2
Average back pressure of ammonia gas in pounds per square inch above the atmosphere	15.8
Average temperature of brine in freezing tanks in degrees Fahr.,	19.7
Total number of cans filled per week	4,389
Ratio of cooling surface of coils in brine tank to can surface	7 to 10
Ratio of brine in tanks to water in cans	1 to 1.2
Ratio of circulating water at condensers to distilled water	26 to 1
Pounds of water evaporated at boilers per pound of coal	8.085
Total horse-power developed by compressor engines	444
Percentage of ice lost in removing from cans	2.2

APPROXIMATE DIVISION OF STEAM IN PER CENTS. OF TOTAL AMOUNT.

Compressor engines	60.1
Live steam admitted directly to condensers	19.7
Steam for pumps, agitator and elevator engines	7.6
Live steam for reboiling distilled water	6.5
Steam for blowers furnishing draft at boilers	5.6
Sprinklers for removing ice from cans	0.5

DATA AND RESULTS OF TESTS IN DETAIL.

BOILER TEST.

There are two Heine Safety boilers, each of 375 horse-power capacity, having McLave grates. Four steam jet blowers under the

two boilers are employed to increase the draft. Before the test was started a mercury well was inserted in the feed-water supply pipe, a pyrometer put into the flue, the lower water meter (there being two) was securely locked, all faucets leading to hydrants, etc., sealed shut with wires, and extra precautions taken that the blow-off cocks were tight.

The feed water, after running through the meter, passed through a sand filter and thence to the cistern, where its surface level was taken at the beginning and end of the test. The dimensions of the cross-section of the cistern are 9 feet 11 inches by 8 feet, the depth being immaterial. From the cistern the water was fed to the boilers after first passing through a Goubert feed-water heater. Two quarts of Diamond Boiler Compound was added daily.

A new supply of coal was put in during the night before the second day's test; this was of a different quality from the first supply, as shown by analysis made on both.

RESULTS OF BOILER TEST.

	April 4.	April 5.
Date of test		
Number of tubes in each boiler	171	171
Diameter of tubes in inches	3½	3½
Length of tubes in feet	16	16
Square feet of heating surface for two boilers	5,540	5,540
Square feet of grate surface	127.2	127.2
Rated capacity in horse-power	750	750
Duration of test in hours	12.25	11.5
Total amount of coal burned in pounds	25,312	22,159
Pounds of coal per hour	2,066	1,927
Percentage of ash (actual conditions)	19	17.1
Percentage of ash (analysis)	16	12
Average steam pressure in pounds per square inch above the atmosphere	96.5	97.8
Average draft (difference between pressure under grate and in chimney in inches of water)	0.33	0.35
Barometer in inches of mercury	29.7	30
Temperature of feed water, degrees Fahr.	187.9	191.9

Temperature of air, degrees Fahr.	69	56
Temperature of stack, degrees Fahr.	373	356
Total amount of water evaporated into dry steam (actual conditions), pounds.	202,952	180,689
Pounds of water evaporated per hour (actual conditions).	16,567	15,712
Pounds of water evaporated per pound of coal (actual conditions).	8.02	8.15
Pounds of water evaporated per pound of coal from and at 212 degrees	8.53	8.64
Pounds of water evaporated per pound of combustible from and at 212 degrees.	10.5	10.4
Pounds of water evaporated per square foot of heating surface per hour	2.9	2.8
Pounds of coal per square foot of grate area per hour.	16.2	15.1
Horse-power actually developed, 70 pounds and 100 degrees feed.	511	483
Square feet of heating surface per horse-power,	10.8	11.4
Percentage of moisture in steam.	Dry	Dry

COAL ANALYSIS.

Date at which coal was burned under the boilers..	April 4.	April 5.
Kind of coal.	Buckwheat and pea.	Buckwheat.
Weight of crucible.	8.175 G	8.175 G
Weight of crucible plus coal.	9.878	9.356
Weight of coal.	1.703	1.181
Per cent. of moisture.	5.5	5.0
Per cent. of volatile and combustible.	5.3	5.0
Per cent. of fixed carbon.	73.2	78.0
Per cent. of ash.	16.0	12.0

CALIBRATION OF WATER METER.

The meter was of the Thomson type, 3-inch size. To calibrate the meter it was disconnected, swung out, and a pipe fitting was made which would lead the water into a barrel that had been previously weighed and found to contain 455 pounds. The

valve was so regulated that the flow was the same as during the boiler test.

Ten observations were made, all of which agreed very well with each other, the meter registering 7.4 cubic feet to every filling of the barrel. From this data the meter rate is 61.5 pounds for each cubic foot registered by the dial.

TEST OF "SCHAEFER'S" PUMP.

The steam to drive this pump was furnished by the boilers of the ice-machine plant, whereas the pump was used for purposes entirely separate from the plant. The exhaust from this pump passed to the condenser of the ice machines.

If this pump had not been in use an additional amount of live steam, equal in weight to the steam exhausted from the pump, would have been required at the condensers. The pump supplied river water to "Schaefer's Brewery," and could not well be shut down.

This pump is a duplex Worthington pump, run at an average speed of 18 strokes per minute, the steam supply being regulated by the head of water pumped against. One-half hour previous to starting the test all the machinery was shut down so as to have no undue condensation. The test was continued for two hours, showing a water consumption of 882 pounds per hour, not including the drip water, which could not be separated from that coming from the remainder of the system.

GENERAL METHOD OF CONDUCTING THE CONTINUOUS TEST OF ONE WEEK.

During the run of one week indicator cards were taken hourly from each engine, and the revolutions, also the pressure of ammonia entering and leaving the compressors, were noted.

The temperature of the brine was taken four times a day, also that of the ice-storage rooms.

An accurate record was taken of the water fed to the boilers, and of that unavoidably wasted. The drip was obtained for the entire week, the amount each day being about constant.

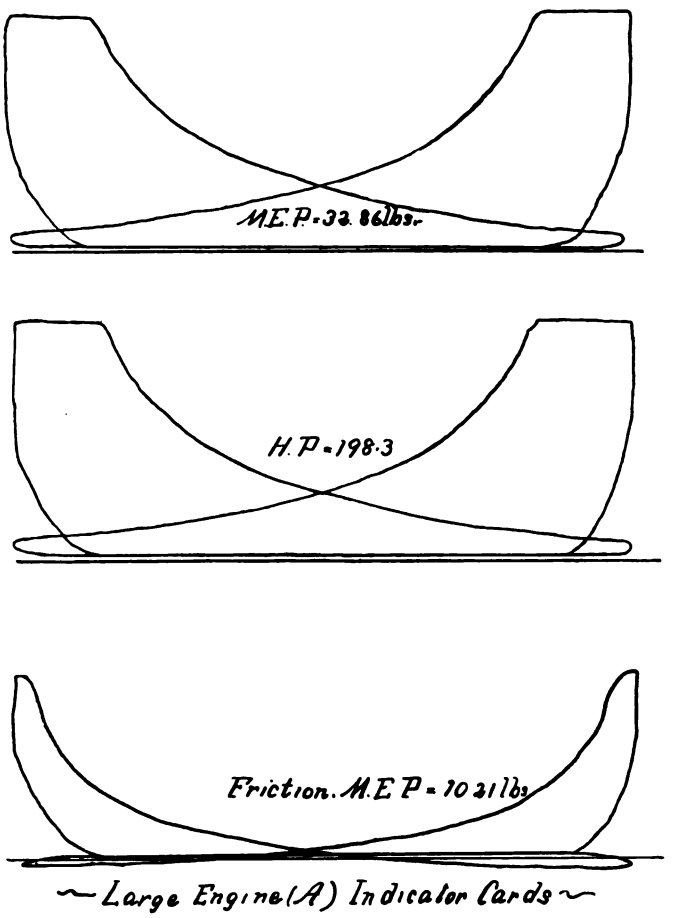

FIG. 2.

A record was taken of the number of ice cakes drawn daily from the tanks; also of the number solidly frozen at the beginning of each day. This last number remained constant up to Friday, May 5, at 7 A. M., when the engines were speeded up a few turns

per minute so as to increase the stock of ice on hand, causing a corresponding increase in the number of cakes solidly frozen over.

In obtaining the ice made per pound of coal no allowance is made for the additional cakes of ice in the tanks at the close of the test, so that the figure given is slightly lower than it would be if such an allowance were made. If the ice made per pound of coal before the time that the engines were speeded up is calculated, it is found to be about 1 per cent. higher than that for the whole week, so that it was considered to be best not to correct for the ice frozen ahead in the tanks at the end of the week, which, if done, would involve approximations and make the figure a less reliable one for every-day practice.

Record of Water Supplied to Boilers from May 1 to May 8.

Date.	Time.	Meter Reading. Cubic Feet.	Tank. Inches.	Gauge Glasses. A	Gauge Glasses. B	Waste. Pounds.	Unavoidable Waste.
May 1	7.00 A. M.	1,767,958	13½	7½	7½	12,782	
" 1	7.00 P. M.	1,771,576	13½	"	"	.....	230 pounds.
" 2	7.00 A. M.	1,771,834	16½	6	6		
" 2	6.45 P. M.	1,775,419	16½	"	"	12,952	365 condenser leak.
" 3	7.00 A. M.	1,775,760	12	8	8	.....	120 pounds.
" 3	6.30 P. M.	1,779,345	12	"	"	12,912	868 trough filled.
" 4	7.00 A. M.	1,779,675	19½	"	"	.....	1,586
" 4	6.30 P. M.	1,783,330	19½	"	"	12,962	868 + 868
" 5	7.00 A. M.	1,783,669	16	"	"		
" 5	6.30 P. M.	1,787,292	16	"	"	12,802	230 + 744 pounds.
" 6	7.00 A. M.	1,787,936	13	"	"		
" 6	6.30 P. M.	1,791,515	13	"	"	12,922	305 pounds.
" 7	7.00 A. M.	1,791,851					
" 7	6.30 P. M.	1,795,458	.....	.....	.....	12,840	
" 8	7.00 A. M.	1,795,923	13½	7½	7½		
						90,172	6,184 pounds.

RESULTS OF CONTINUOUS TEST OF ONE WEEK.

Running time per day (average) in hours		11.6
Number of days		7
Average pressure in pounds per square inch above the atmosphere.	Boiler	101.6
	Ammonia gas in condenser	135.2
	Ammonia gas in refrigerating coils,	15.8

Mean effective pressures in pounds per square inch.	Compressor A	32.88
	Compressor B	32.61
	Compressor C	32.35
Revolutions per minute (average).	Compressor A	45.3
	Compressor B	45.2
	Compressor C	45.1
Total horse-power		444
Total water metered during week, pounds		1,552,998
Unavoidable waste, pounds		6,184
Water actually used, pounds		1,546,814
Total number of cans filled during week		4,389
Total amount net ice produced per week		1,362,053*
Total amount of waste drip in pounds per week		90,172
Total amount of water used by blowers per week, running at eight hours per day, as found by independent test of blowers		91,654
Water consumed by sprinkler per week, as per independent test, pounds		8,400
Balance representing the steam used in the evenings by "Schaefer's" pump and decreased by hydrants, reboiler evaporation, drip of salt-water pumps, agitator engine, elevator, and loss by melting of ice in cans, pounds		5,465
Pounds of coal consumed per week, boiler evaporation 8.085 pounds		191,320
Ice made per pound of coal		7.12
Average temperature of brine in degrees Fahrenheit.	7 A. M.	23.85
	10 A. M.	20.59
	2 P. M.	17.77
	7 P. M	16.62
Rate of radiation during night per hour, degrees Fahr.		0.603
Average temperature of ice-storage rooms.	Upper	30.3
	Lower	31.5
Amount of water used for condensing purposes per week		35,422,463
Pounds of ice per horse-power per hour		37.8
Ice manufactured per day of 12 hours, in tons		97

* A small portion of this water is furnished by "Schaefer's" pump running overtime, so that it cannot be directly compared with the total water given above, which was measured only in the daytime while the entire plant was running.

ICE.

In finding the average weights of the cakes of ice 10 cans containing ice were weighed from each tank during the day. After the ice was removed the cans and ice were weighed separately, from which the amount lost in removing ice from cans, chiefly due to loss by melting during the sprinkling process, was obtained. The average weights of cakes from each tank were as follows:

TANKS.					
[1]	[2]	[3]	[4]	[5]	[6]
308.9	310.3	303.5	300.8	315.4	320.2

The difference in the average weights in the several tanks is due to the fact that the mechanical fillers do not always trip at the same level of water in the cans.

The average weight of the cans in the tanks 1, 2, 3, and 4 is 75 pounds; that of those in 5 and 6 is 96.3 pounds. The dimensions of the cans, which are slightly tapered, are: Height, 44 inches; breadth at top 11¼ inches, and at bottom 10½ inches; length at top 22½ inches, and at bottom 21½ inches. They are filled to within 9 inches of the top, expanding in freezing to within 6 inches. In tanks 1, 2, 3, and 4 there are 54 coils running through the space between the cans. These coils are 21 feet long, having eight lengths of 2-inch pipe to each coil.

The tanks are 23 feet by 70 feet, the brine having a depth of 3 feet 4 inches. The cans are sunk to within 7½ inches of their top.

In tank 5 there are 20 coils of 2-inch pipe 72 feet long and six lengths to a coil. This tank is 24 feet by 74 feet, the depth of brine in it being 3 feet. In tank 6 the number of coils is 23, each containing six lengths of 2-inch pipe 72 feet long. The size of the tank is 28 feet by 74 feet, and the depth of brine is 3 feet.

From this data and observations made the following results were obtained:

Total number of cans in tanks	2,679
Surface of cooling coils in square feet	34,043
Cooling surface per can in square feet	18.5

Surface of cans immersed in square feet	49,561.5
Ratio of cooling to can surface	7 to 10
Time taken to freeze can in hours	60
Quantity of brine in tanks in cubic feet	12,692
Quantity of water in cans in cubic feet	15,284
Ratio of brine to water in cans	1 to 1.2
Temperature of water entering cans, degrees Fahr	62
Temperature of water used at sprinklers, degrees Fahr	96
Total number of cans in use	3,176

APPROXIMATE DIVISION OF TOTAL STEAM USED IN ORDER TO DETERMINE THE AMOUNT CONSUMED BY THE VARIOUS PROCESSES.

Tests were made to determine the steam used at the reboiler for the distilled water, at the sprinklers to remove the ice from the cans, at the jet blowers to produce draft at the boilers, and by the pumps, agitator engines, etc. These were of an approximate nature, but serve in a general way to show the distribution of the total steam.

The steam to drive the engines was assumed at 26 pounds per hour per horse-power, which was known to be the correct figure for the conditions involved. The live steam admitted directly to the condensers was determined by direct experiment, in which the admission valve was set at the average opening noted during the test of one week, and by taking the difference between the total steam and all other quantities except the live steam admitted to the condensers. A mean of the two values is given in the table.

The details of the tests and the final results follow:

TEST OF REBOILER.

After the water leaves the condenser it enters a tank known as the reboiler, in which it is boiled by live steam entering it directly. The test was made to determine the amount of this live steam injected. Having previously determined that the valve controlling the admission of steam is given a half-turn, it was so set during the

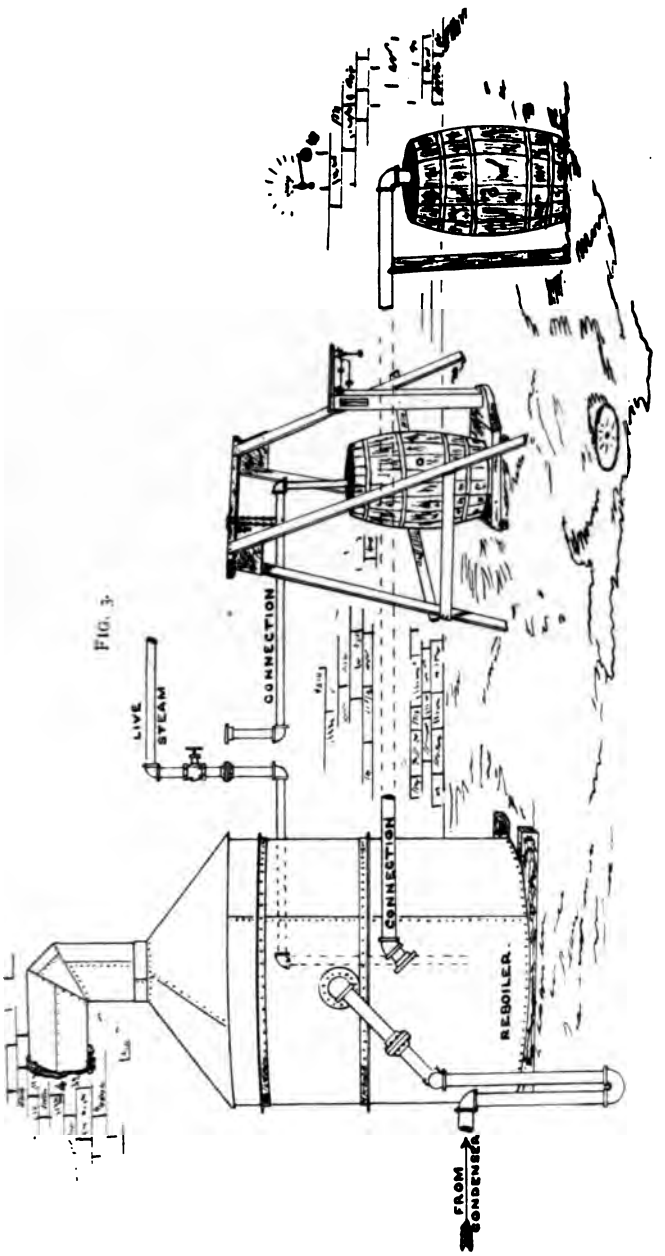

FIG. 3.

REBOILER TEST
ALSO
SHOWING CONNECTION MADE FOR MEASURING CONDENSED WATER.

test. A flange between this valve and the reboiler was disconnected and a pipe fitting made similar to the one running into the reboiler which conducted the steam into a barrel partially filled with cold water, this latter being placed on a platform scale. Steam was allowed to run into this water for various lengths of time, weighings being taken. Precautions were taken that no condensed steam lay in the pipe. For general arrangement of apparatus see Fig. 3.

The result of the test showed a consumption of steam injected of 1,251 pounds per hour.

DETERMINATION OF THE STEAM REQUIRED TO HEAT THE WATER SPRINKLED ON THE CANS IN REMOVING THE ICE FROM THEM.

A small Knowles pump was used to supply the sprinklers, the water for this being drawn from a tank which is constantly replenished by the same water returning from the sprinklers. This water is heated up to an average temperature of 96 degrees by a half-inch steam injection.

The test was carried on in a similar manner to the reboiler test, except that as the controlling valve was not set at a constant position, but varied from one-half turn to one-eighth, it was necessary to take several readings with the valve set at intermediate positions and obtain an average. This valve is open at an average of six hours per day. As a result of this test it was found that the sprinklers used 200 pounds of steam per hour.

TEST OF JET BLOWERS.

Four jet blowers situated under the boilers were run at an average of eight hours per day, the valves being given a half-turn. During the test the jets were turned outward so as not to cause too much steaming, as very little steam was generated. "Schaefer's" pump alone was running, for which a correction had to be made The boiler pressure was preserved at the normal figure.

The test showed a consumption of steam by the blowers of 1,550 pounds per hour, or 86,800 pounds per week.

TEST TO DETERMINE THE AMOUNT OF LIVE STEAM ADMITTED DIRECTLY TO THE CONDENSERS.

In order to obtain the amount of live steam directly injected into the condensers it was necessary to run everything except the engines for two hours. The live-steam valve was set at its average position for the week, and the amount of condensed steam measured off in barrels at the condenser. The live steam was then shut off and the test continued for an hour. The difference of water consumed per hour gave the amount of live steam injected.

The live steam was also found by taking the amount remaining of the total steam when that used by all other sources was estimated. The average of the two figures thus obtained gave 304,100 pounds per week.

TOTAL WEIGHT OF STEAM USED PER WEEK FOR VARIOUS PURPOSES.

Three engines driving ammonia compressors	929,300	pounds.
"Schaefer's" pump	58,400	"
Reboiler for distilled water	100,700	"
Sprinklers to remove ice from cans	8,400	"
Blowers to produce draft at boilers	86,800	"
Sum	1,183,600	"
Total steam for all purposes	1,546,800	"
Difference, or live steam admitted directly to condensers plus that for pumps, elevator and agitator engines	363,200	"
Live steam admitted directly to condensers	245,700	"
Difference, or steam for pumps, elevator and agitator engines	117,500	"
Equivalent live steam if "Schaefer's" pump had not been run, and the steam used by it exhausted directly into the condenser, 245,700 + 58,400 =	304,100	"

QUANTITIES IN PER CENTS. OF TOTAL STEAM.

Compressor engines	60.1	per cent.
Live steam admitted directly to condensers	19.7	"
Steam for pumps, agitator and elevator engines	7.6	"
Live steam for reboiling distilled water	6.5	"
Steam for blowers to produce draft at boilers	5.6	"
Sprinklers for removing ice from cans	0.5	"

SOME OBSERVATIONS ON SHOP TRAINING.

BY WILLIAM S. ALDRICH, '84.

THAT action and reaction are equal and in opposite directions has been operating for some time as a law of motion in general education. It might be more proper to say that the reactions are almost equal to the actions. For a certain conservatism soon develops, acting as a retarding force whenever the question arises (as it is sure to do) respecting the propriety of returning to a former condition of affairs. All movements have their day. The pendulum-like character of fads and fashions finds a counterpart only too often in more serious matters.

After a score of years of shopwork as a factor in the education of the mechanical engineer, its expediency has come to be questioned by the rising generation or—the falling generation. Those who placed shopwork on the curriculum had not had it that way themselves. They obtained their knowledge of shopwork by shopwork; from 7 to 12, and from 1 till 6, ten hours a day, for at least fifty weeks of the year, and from four to seven years of the most valuable formative period of their lives, from an educational standpoint. It seemed to them that it was a good idea, which some one suggested, that perhaps shopwork and methods, if not also principles, might be taught as a proposition of Euclid.

The fathers of technical education in this country were going to prepare better ways for their sons. Instead of spending six months at the drill press, their sons should learn how to drill a straight hole in six hours. And what more was required? Longer time would develop a certain dexterity and resourcefulness, often best learned in country repair shops. These, with the skill that comes of repeated operations, would make them all the more

valuable to their employers if engaged all their lives in drilling holes; but, surely, scarcely more valuable to themselves in the possession of the "know how" of working the drill press.

The sons have now come to the point of thinking for themselves; and, as usual, with the desire to make matters easier for their sons, to make one more step in the direction of gaining the royal road to learning. Many of them have seen how little use they have had occasion to make of their shop training, and draw the conclusion that it might advantageously be abridged, or even abolished. Perhaps they would substitute the "inspection method," a plan which has its earnest advocates, and which seems quite plausible on the surface, if not a few strata below the surface. Others have gotten into fields of work requiring all the knowledge of shopwork they obtained at the technical school, and all the knowledge they could get since, often, it is true, by their own adoption of the "inspection method," and in other cases by actually working for a year or two in the shops after graduation.

We shall not enter upon the discussion of these, as to which is the best post-graduate plan to pursue to get what is most needed in the field of shopwork or supervision. The value of any training in handicraft is questionable, after 21 years of age, but fully recognized as extremely valuable if given its proper period in the growth of the boy—from 14 to 21 years. With advancing years adaptations to new muscular movements become more and more difficult, while the intellectual grasp increases, at least it ought to; and the power to acquire knowledge by observation and reasoning processes opens up new methods with each succeeding year.

The following plans have been tried in teaching shopwork in well-known and representative technical schools throughout the country:

1. The "inspection method," by which the student examines, measures, sketches, and reports upon the work of skilled workmen in some selected shop, but performs no actual shopwork himself.

2. The manual training method, or "shop exercise" system, in which the student is carried through a graded series of exercises in the handling of shop tools and appliances, and the making of certain typical forms found in construction, selected as being representative of the method of handling the various tools in working the principal kinds of materials used in construction.

3. The job-work system, in which the student is engaged entirely upon the construction of apparatus and machinery for use in the shops of the school.

4. The combination of the exercise and the job-work systems whereby the student is taken through a short graded course of shop exercises, and put at work upon making appliances for the shops or laboratories of the school for the remainder of the course.

5. The manufacturing shop system, in which the student at once, or very soon after his taking up shopwork, begins work side by side with skilled mechanics, under their continual supervision and instruction, and engaged upon the manufacture of commercial articles, as well as machinery for the shops of the school.

These systems and their several variations have many adherents in the different manual training and technical high schools as well as in the engineering schools. Upon a close study of the school exhibits at the World's Fair, it became apparent how the manual training idea had spread during the last ten years, and with a remarkable uniformity of output. Whether the early schools were right or wrong, they have been almost literally copied in the details of their methods and exercises for shop instruction. It will appear however, that they have reduced the matter to a definite standpoint, so far as the exercise is concerned, namely, it shall be purely educational in its nature. If, at the end of the course, it becomes a project in the form of an engine, a dynamo, a lathe, a bridge model, or a stair model, it is with the idea of summing up, as it were, the several constructive features that have been considered in detail during the three years' course of shopwork.

Manual training being the production of fundamental form in material by the direct use of a hand tool, it has developed as a branch of public education with wonderful rapidity since its first inception, about ten years ago. It limits logically-developed courses of shop instruction strictly to the educational value of such instruction by not entering the industrial, commercial, or trade elements which are invariably connected therewith. These latter are properly brought, to a very limited and guarded extent, however, into a course of instruction in the mechanic arts of our technical schools.

Underlying all the constructive arts are the fundamental geometric forms, such as the circle and polygons, and the three round bodies, sphere, cone, and cylinder, with the helical or screw surface. In relation to the constructive arts, therefore, the first work of manual training properly takes up the production of these fundamental forms with the fundamental tools used in working the material selected for the embodiment of the form; and, with such treatment of the material in each case, as shall fully acquaint the student with the characteristics of that material, and the ordinary capabilities of the tool used in working the same.

The uniformity of output of the manual training schools, as exhibited at the World's Fair, may be accounted for, in part at least, by their avowed selection of fundamental constructive forms, and these, too, as nearly as possible along geometric lines. They endeavor to reach down to the bottom of the matter, to begin at the "A B C" of construction, and build a part of the foundation course. In this way such schools offer the best possible preparation for the schools of technology, at least, so far as shop training goes; and, in many instances, their collateral studies are as well adapted to prepare for entering the school of technology, as more pretentious courses in the adjacent city high schools. Manual training schools are becoming feeders for our technical schools. Is it probable that the present effort to reduce the shopwork in the latter comes from a belief that almost all of the necessary shopwork is

so well undertaken and carried through by the manual training schools?

If all students entering the technical school for their professional courses had had their preparatory courses in the manual training schools, certainly the shop courses of the former might be advantageously altered to meet these changed conditions, and altered so as to give more attention to the development of constructive mechanics than is possible at present. More thorough preparation is what is called for on all sides. In the matter of shop training it is almost impossible to advance further than at present, for the simple reason that many students come to the technical school with no previous knowledge of the handling of tools and of the "resistance of material." An eminent authority has remarked that those students who had worked in the shops before coming to the technical school were not so far advanced as they thought they would be, in this line, as almost all of their previous work had been done with no previous idea of its being made educational, so that much, if not all, had to be carefully developed from the first principles, even as in manual training.

From whatever point it is viewed, the training given in the representative manual training schools to-day, is most admirably adapted to form the foundation for the shopwork of the technical schools. Why not make it a requirement for admission? If we wish to have more time to give to applied mathematics in a course of technology, we raise the requirements in pure mathematics. The same may be said of every branch of study. Require previous training in shopwork, and it will be met. It can as well be supplied, to-day, as any course of study. The fact is, that whatever higher education has required for admission to its courses, lower education has prepared for.

The following is quoted* as a matter of interest, in relation to one of the oldest and most thoroughly representative manual training schools:

**Philadelphia Public Ledger.*

"Seventy per cent. of the three hundred graduates are employed in occupations requiring a high degree of intelligence, as well as skill of hand; and twenty-five per cent. have been so inspired with a desire for higher education, that they have become students in colleges, universities, and technical schools. The oldest graduates left the school only six years ago, yet of that first class fourteen out of fifty-seven are superintendents or managers of industrial establishments; others are in business for themselves, or are employed as draughtsmen, teachers, civil engineers, etc., no less than thirty-seven being employed in occupations for which their school training specially fitted them. It must not be inferred that the other twenty have not been benefited by their school training, for every one of the class is in honorable employment, or is a student in higher schools; all are accounted for. The same thing may be said of the other classes, except that, the graduates, being younger, are in somewhat less responsible positions, and a larger proportion are still students."

Passing now to the other end of the line, we note the Worcester Polytechnic Institute as standing for the longest while at the head and front of the manufacturing shop system. At a recent date the opinions of its graduates on the subject of reducing its shop courses were collected and published in pamphlet form. Some of the replies are interesting and valuable. Says one: "When I came to designing machinery, I found that I had none too much shop practice. One cannot become a good draughtsman unless he is well acquainted with the pattern shop, foundry, and machine shop. The chief failing of the draughtsmen with whom I have had to do has been their lack of experience in the shop." Another, from large experience gained at home and abroad, replied: "All have heartily indorsed the great and vital importance of combining with a technical education a large amount of shopwork, and nearly all have regretted that they have not had more." Still another says: "What we need is not men who are extraordinary mathematicians and fancy draughtsmen, but men who have had some experience as mechanics, and know how to put everything on a drawing that belongs there, in a clear and complete manner."

With the growing demands of the mechanical laboratory in the technical school, the ever-present demands of every department for more time, it would seem, at first sight, that perhaps shopwork might be abridged, or even left to the manual training school; but such a course will be fatal. Aside from the mathematical preparation required for laboratory work, the next best comes from the shop. Experimental mechanics is greatly indebted to thorough preparation in constructive mechanics. This phase of the question has not yet had time to develop itself in practical engineering life; it is too soon. The aid which shopwork has given to constructive drawing is invaluable and ever recognized.

We doubt not that the remarkable exhibit of the Germans, at the World's Fair, compared with their insignificant exhibit at the Centennial, has been due in no small degree to the spreading influence of their technically educated young men into the shops and factories. Not long ago, it is reported that a noted German manufacturing establishment put out the sign: "No technical graduates need apply." What has been the result, not only in this instance, but in many of a similar nature? Technical graduates have not forced themselves where not wanted, but have gone into the shops, shipyards, etc., and have become a power for good in bringing their knowledge and methods to bear in the most needed fields.

Not less shopwork, but more; not less time given to it, but more; not a lowering of one of the important branches of the young engineer's training, but a decided raising of its standards. It appears, also, that the manual training school may be found a useful preparation for the technical school; that in this way, more advanced work may be taken in hand in the technical course; more approach made to the competitive conditions of manufacturing; and that it may be possible, in this way, to introduce the "shop-order" system of work and accounts in present technical schools.

CURIOUS CUSTOM-HOUSE RULINGS.

IT is probably well known that for the aid and encouragement of institutions of education, most of which have been founded and are supported by the munificence of private individuals, Congress long ago passed acts intended to remit duties on articles imported from abroad for the use of such institutions in their work of instruction. Until quite recently this intention of Congress has been carried out by the officers of the Treasury Department in a rational way, so as to secure the object aimed at, as far as possible; but recently some very curious rulings and decisions have been made, which, as specimens of intelligent discrimination, are worthy of being put on record.

For example, it has been decided that while chemical liquids or solids may be imported free for the use of the chemical department of a college, duty must be paid on the bottles containing them, if, as is of course necessary in many cases, these bottles are of glass.

Again, while glass beakers, test tubes and the like may come in free to colleges, funnels must pay 45 per cent. duty, and racks for holding the test tubes while in use, must pay 35 per cent., evaporating dishes 55 per cent., and filter papers 15 per cent.

The reason for this distinction given in certain instances is as amusing as the discrimination is wonderful. It is because the dutiable articles differ from the others in failing to "develop and exhibit natural forces."

It will be a good subject for a scientific thesis, we think, to explain in what way a beaker glass "exhibits and develops a natural force" which a funnel or evaporating dish fails to show.

There may be, of course, some occult motives of policy underlying these rulings and decisions, but for the credit of those concerned it is unfortunate that on their face they should carry such an aspect of fatuity.

H. M.

REVIEW AND EXPERIMENTAL DETERMINATION OF THE TRANSMISSION OF HEAT FROM STEAM TO WATER THROUGH COILS OF IRON PIPE.

BY HENRY G. C. KOPP, '93, AND FRED. J. MEYSTRE, '93.*

THIS review was undertaken in order to collect and establish reliable data on the abstraction of heat from steam by water.

In condensing and steam-heating apparatus the most common forms of the surface of conduction are those of metallic plates, as in double-bottom boilers, and of coils.

At first sight, it may appear as if a square foot of condensing surface ought to produce the same results, whether in the form of plate or pipe. But, in reality, there are points of difference which materially affect the results obtained. Plates being usually smoother than piping, the transmission of heat is less rapid in the former, and consequently the condensing power is less.

In plates or double bottoms there is a greater chance of air being mixed with the steam, this being very detrimental to the condensing power of the surface. Pipe surfaces, only, will therefore be considered. The condensing power of a given area depends upon the material of which the pipe is made, its thickness, the difference between the temperature of the steam contained in the pipes and that of the liquid to be heated, and upon whether both ends of the coil are in communication with the boiler, or whether one end is open to the atmosphere.

When one end of the coil is open to the atmosphere the pressure of the steam in the coil gradually diminishes from the receiving to the open end, causing a corresponding decrease in the temperature of the steam, and consequently less heat is transmitted through the coil.

* Abstract from graduation thesis.

In order to get the exact amount of heat transmitted it is necessary to rely only on the results of direct experiments, as theoretical assumptions scarcely agree with practical conditions.

From all available records, it appears that copper has been the metal most frequently employed in previous experiments to determine the condensing power of pipe surface under different conditions.

TESTS MADE WITH COPPER COILS.

Experiments have been conducted by MM. Laurens and Thomas, in which the coil employed was copper, 137 feet 9.5 inches long, 1.34 inches outside diameter, having a surface of 48.25 square feet. During the test, steam, at a pressure of 30 pounds above the atmosphere, was admitted into the coil which was submerged in 880 pounds of water, the temperature of which was 44.4° Fahr. In four minutes the water boiled, and in eleven minutes more 550 pounds of water had been evaporated. The condensing power of the surface was measured by the work done, the amount differing considerably during the two operations mentioned.

During the first four minutes the work was done in heating the water and amounted to

$$(212 - 44.4)\ 880 \text{ thermal units,}$$

which, per square foot per hour, reduces to

$$\frac{(212 - 44.4)\ 880 \times 60}{48.25 \times 4} \text{ pound degrees} = 45850 \text{ heat units.}$$

M. Peclet is authority for the statement that the transmitting power varies directly as the difference of temperature on the two sides of a metal surface.

Therefore, we get for a difference of one degree between the temperatures of the steam and water, taking a mean between the initial and final temperatures of the water as its condensing temperature,

$$\frac{45850}{(274.4 - 128.2)} = 314 \text{ B. T. U.}$$

In the second operation, 550 pounds were evaporated at 212 degrees. The total heat of steam at 212 degrees being 1178.6 degrees, there were

$(1178.6 - 212) \times 550 = 966.6 \times 550 = 531630$ B. T. U., giving as a final result

$$\frac{531630 \times 60}{48.25 \times 11 \times (274.4 - 212)} = 963 \text{ B. T. U.}$$

Another series of experiments was undertaken by M. Havrez (*Revue Universelle*, January, 1868), in which a copper coil, 1.57 inches diameter, having an exposed surface of 5.85 square feet, was used. His results differ materially from those of Laurens and Thomas, this being accounted for by the fact that the coil was incrusted to some extent.

The amount of steam used was obtained by weighing the water of condensation.

The preceding and other experiments made by M. Havrez are given in the following table:

Comparison of Results Obtained During Experiments on Heating by Steam Pipes. *

Reference Number.	Name of Experimenter.	Steam. Pressure above Atmosphere. Pounds.	Steam. Temperature. Degrees Fahr.	Water. Temper. Deg. F. Initial.	Water. Temper. Deg. F. Final.	Mean Difference Between the Temperature of the Steam and Water.	Quantity of Steam Condensed Pounds. Per Square Foot of Pipe Surface per Hour.	Quantity of Steam Condensed Pounds. Per Square Foot of Surface per Degree of Difference of Temperature per Hour.	Remarks.
1	Laurens and Thomas	30	274.4	44.4	212	146.2	46.5	.318	The boiling vessel and pipes had to be heated during the first experiment.
2	Laurens and Thomas	30	274.4	212	212	62.4	61.58	.987	The boiling vessel and pipes had to be heated during the first experiment.
3	Laurens and Thomas	15	250.4	212	212	38.4	39.63	1.032	The boiling vessel and pipes had to be heated during the first experiment.
4	Havrez	52	300.	68	212	160	42.25	.264	Pipe used in the following experiments was incrusted.
5	"	74	306.	68	212	166	45.0	.271	
6	"	74	306.	104	212	148	39.0	.27	
7	"	52	300.	212	212	88	10.15	.115	Water boiling gently.
8	"	74	306.	212	212	94	16.35	.174	Water boiling violently.
9	"	74	306.	212	212	94	7.89	.084	Water boiling gently.

* *Engineering*, 1868, p. 158.

TESTS MADE WITH IRON COILS.

Few tests have been made on the transmission of heat through iron coils, copper being more generally used owing to its greater conductivity.

Messrs. A. M. Perkins & Son, in making experiments on the subject, found that wrought-iron pipes, supplied with steam at a pressure of 100 pounds per square inch, and immersed in water at a temperature of 212 degrees, will condense per hour, for every 2 square feet of immersed surface, the steam resulting from the evaporation of a cubic foot of water.

If, however, the steam be supplied at 10 pounds pressure, 10 square feet of surface will, under similar conditions, be required to condense the same weight of steam, this being the result partly of the greater difference in temperatures of steam and water, in the former than in the latter case, and also to the fact that steam at 10 pounds must part with a greater amount of heat during condensation than if at 100 pounds.

They obtain for the values of the heat transmitted per hour per square foot per 1 degree difference of temperature, 215 and 208.2 B. T. U. respectively.

Thos. Box, in his treatise on "Heat," reports an experiment made by himself in which he used a thin welded tube of wrought iron, 1.5 inches outside diameter and about one-sixteenth inch thick, fixed vertically in a vessel of water, 12 inches square, and 3 feet 7 inches deep in the water, steam being so admitted as to prevent the carrying over of any priming from the boiler. The vertical pipe was supplied with an air vent at the top. By means of an open cock at the bottom of the pipe the condensed steam was continually drawn off.

The weight of the condensing water was 223 pounds, and was stirred well to produce uniformity of temperature. The exposed surface of the tube was 1.4 square feet. In one experiment the water was raised from 65 degrees to 110 degrees in 15 minutes, and

10.218 pounds of steam were condensed. The mean temperature of the water was 87.5 degrees. The difference between that and the temperature of the steam was 124 5 degrees, giving as heat transmitted, 230 B. T. U. per hour, per square foot, per 1 degree of difference.

Two other experiments gave 207 and 210 respectively.

Using the values obtained in the experiments, Box developed an approximate curve from which, in turn, he obtained values for other temperatures, as given in the following table:

Temperature of Water to be Heated. Degrees Fahr.	Heat Units per Square Foot per Hour per 1 Degree Difference of Temperature of Steam and Water.
40	185
60	193
80	209
100	233
120	265
140	305
160	353
180	430
200	600

M. Havrez made experiments on a cast-iron boiler having a double bottom. Its dimensions were 18.5 inches in diameter, 13.5 inches deep, having a jacketed surface of 6.576 square feet.

His tests resulted as follows:

Heating of Water.

STEAM.			WATER.			
Total Pressure. Lbs.	Temperature, Degrees Fahr.	Weight Condensed per Square Foot per Degree Difference of Temperature per Hour. Lbs.	Quantity Heated. Lbs.	Temperature, Degrees Fahr.	Time of Heating. Min.	Heat Transmitted per Square Foot per Hour per Degree Difference of Temperature.
67	300	.066	229.7	80	25	69.9
67	300	.088	237.6	68	22	93.54

Evaporating of Water.

STEAM.		Weight of Water Evaporated from 212 Degrees per Degree.	Weight Water Condensed per Square Foot per Degree Difference per Hour.	Heat Utilized from One Pound of Steam.	Time for Evaporation.	Heat Transmitted per Hour per Square Foot per Degree Difference of Temperature.
Pressure. Lbs.	Temperature. Degrees Fahr.	Lbs.	Lbs.	B. T. U.	Min.	B. T. U.
67	300	8.8	.091	961	10	87.45
67	300	11.44	.118	961	10	113.40

The results of all the foregoing experiments have been collected in the following table:

Experimenter.	Character of Surface.	STEAM CONDENSED PER SQUARE FT. PER DEGREE DIFFERENCE OF TEMPERATURE PER HOUR.		HEAT TRANSMITTED PER SQUARE FT. PER DEGREE DIFFERENCE OF TEMPERATURE PER HOUR.		Remarks.
		Heating. Pounds.	Evaporating. Pounds.	Heating. B. T. U.	Evaporating B. T. U.	
Laurens..	Copper coil...	.292	.981	315	974	
" ..	2 Copper coils.	....	1.20	....	1120	
Havrez ..	Copper coil...	.268	1.26	280	120	
Perkins ..	Iron coil... ..	....	.24	....	215	Steam pressure = 100.
" ..	" "	....	.22	....	208.2	" " = 10.
Box.....	Iron tube.....	.235	....	230	. ..	
"	" "	.196	....	207	....	
"	" "	.206	....	210	....	
Havrez ..	Cast-iron boiler	.077	.105	82	100	

From the above it would appear that the efficiency of iron surfaces is less than that of copper coils, plate surfaces being far inferior.

In all experiments made up to the present time, it appears that the temperature of the condensing water was allowed to rise, a mean between the initial and final temperatures being accepted as the effective temperature. But as water becomes warmer it circulates more rapidly, thereby causing the water surrounding the coil to become agitated and replaced by cooler water, which allows more heat to be transmitted.

Again, in accepting the mean temperature as that of the condensing medium, the assumption is made that the rate of condensation is in direct proportion to the temperature of the condensing water.

In order to correct and avoid any error arising from these assumptions and approximations, the following experiments were undertaken, in which all the conditions were constant, especial attention being paid to the temperature of the condensing water which was constant during any one test. Two series of experiments were made, one in which the steam pressure was maintained at 60 pounds above the atmosphere, and the other in which the pressure was 10 pounds above the atmosphere.

The work of arranging the apparatus necessary to make the experiments was begun in the basement of Stevens Institute, in the latter part of March, and the experiments occupied a period of two months, working seven hours daily.

Each series consisted of several tests made with the temperature of the condensing water varying by 20 degrees from 80 degrees to 200 degrees inclusive, the results being given in the following pages.

DESCRIPTION OF APPARATUS.

The apparatus used in the tests was designed to secure the greatest possible accuracy in obtaining the data necessary for calculating the results.

The main considerations were the maintenance of a uniform pressure throughout the coil, providing at the same time for the

free outflow of the condensed steam, in order to obtain at all times the full efficiency of the conducting surface.

A second requirement was a continual stirring of the condensing water in order to secure uniformity of temperature, the temperature of the latter being regulated by means of a steam pipe, shown at A, Fig. 1, passing directly from the boilers to the bottom of the tank, and by a cold-water pipe C, emptying into the top. The tank B was 7 feet high and 5 feet in diameter. The stirring was accomplished by drawing the water from the bottom of the tank, at D, and returning it to the top through a branched pipe E, for which purpose a steam pump F was employed.

The coil G consisted of standard wrought-iron piping 1 inch in diameter, arranged in four loops, each being 2 feet 10 inches long, having an entire exposed exterior surface of 9.36 square feet. It was submerged in the centre of the tank B, steam being admitted through the valve H, at its upper extremity, and passing out through the lower extremity at the side of the tank at I. To secure the free outflow of the condensed steam, a "water-glass" J was so arranged at the outlet I that, by throttling at K, the level of the water in the glass could be maintained constant, thus preventing any variation of pressure in the coil G, and any steam from passing through. After passing through the water-glass the condensed steam was led directly into a weighing barrel L.

The steam for the coil was led from the boilers past a drip M, and then over a row of Bunsen burners N, in order to prevent the possibility of any water being carried over from the boilers. The steam was slightly superheated so that the total heat at the given pressure could be accurately ascertained.

Thermometer cups O were placed at the entrance of the coil to obtain the temperature of the steam, at the outlet P of the condensed steam, and at the outlet of the tank D. A steam gauge was also placed at O.

The height of the water in the tank B was maintained constant, the long water-glass R being used for this purpose.

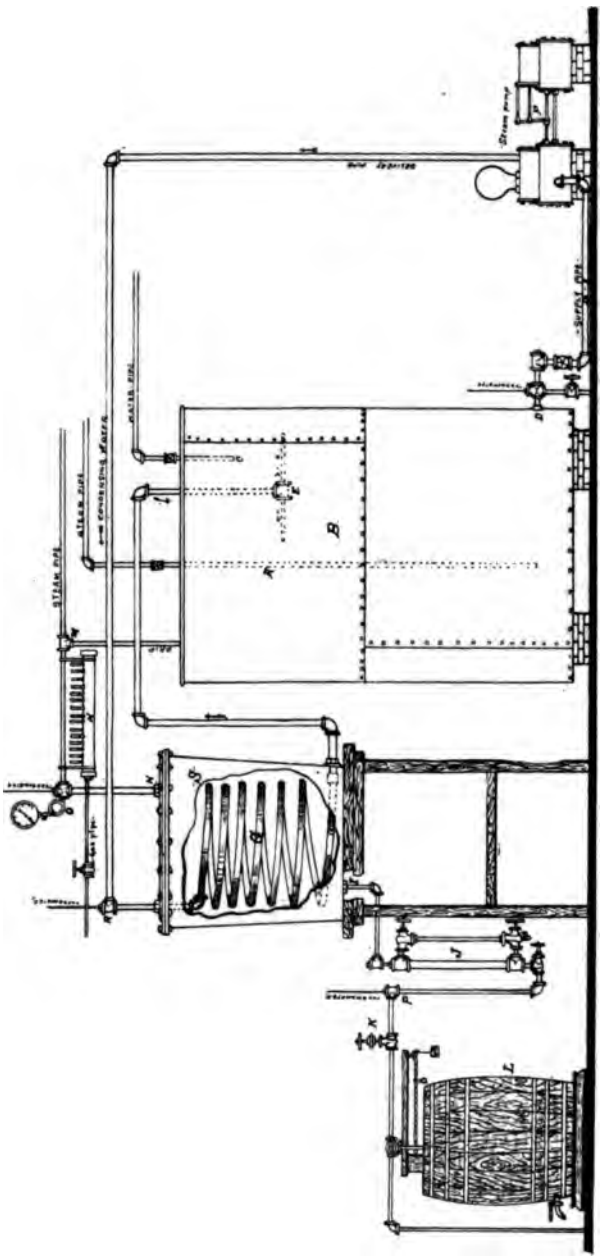

FIG. 1.

METHOD OF CALCULATION.

In the heating of water by steam, the abstraction of heat from the steam causes condensation, the quantity of water produced in this way being a direct measure of the amount of heat transmitted, since the number of thermal units absorbed by the condensing water will be equivalent to the number which would be required to raise the temperature of the condensed steam to the boiling point corresponding to the given pressure, evaporate it, and then raise the vapor through the number of degrees of superheating. Therefore, letting

T_1 be the temperature of steam before entering,

T_2 be the temperature of saturated steam,

T_3 be the temperature of the condensed steam,

T_4 be the temperature of the condensing water,

h_e be the latent heat of evaporation,

S be the number of square feet of radiating surface,

.48 be the specific heat of gaseous steam,

Q be the number of pounds of steam condensed in t minutes at constant pressure, the heat transmitted in any given time t will be

$$[(T_1 - T_2)\ .48 + h_e + (T_2 - T_3)] \times Q.$$

Then the number of thermal units transmitted from the steam to the water, per hour, per square foot of surface, for a difference of one degree between the condensing water and the steam, will be

$$\frac{60\,Q}{S\,t} \times \frac{(T_1 - T_2)\ .48 + h_e + (T_2 - T_3)}{(T_2 - T_4)}$$

The values of h_e and T_2 are taken from a table of the properties of saturated steam.

In making the tests each run was of 20 minutes duration. Readings were taken every five minutes, the average being substituted in the formula. The averages of the first series of tests are reported in the following table:

TABLE I.—DATA TAKEN DURING EXPERIMENT I.

Steam Inside a Coil of One-Inch Standard Iron Pipe and Condensing Water on the Outside of the Same. Pressure of Steam about 60 Pounds per Square Inch above the Atmosphere.

Number of Test.	Pressure of Steam in Pounds per Square Inch above Atmosphere.	Temperature of Condensing Water in Degrees Fahr.	Temperature of Steam at Entrance in Degrees Fahr.	Temperature of Condensed Steam in Degrees Fahr.	Weight of Condensed Steam in Pounds.	Height of Condensing Water in Inches.
1	59.6	80.4	311.8	279.0	205.5	67.
2	59.5	80.4	311.6	267.6	194.25	55.9
3	60.	79.5	310.6	266.2	197.5	67.
4	60.	100.2	312.0	272.6	185.5	67.
5	59.5	100.	314.0	267.4	176.	55.5
6	59.8	100.	311.0	260.8	174.75	55.5
7	60.	119.8	310.2	266.2	167.75	67.
8	60.	119.8	311.2	267.4	168.75	67.
9	60.	140.2	309.2	272.6	153.25	67.
10	60.	139.6	310.2	275.4	153.	67.
11	60.	139.6	312.4	274.	150.	57.7
12	60.	160.	306.8	276 0	129.5	55.8
13	60.	159.8	310.0	274.0	134.	55.5
14	60.	157.6	308.4	280.0	141.75	60.9
15	60.	180.4	311.0	274.0	127.25	67.
16	60.	180.0	310.0	273.2	127.75	67.
17	60.	199.2	309.6	272.4	112.5	67.
18	60.	200.0	309.6	274.8	112.5	67.

TABLE II.—RESULTS OF EXPERIMENT I.

Steam Inside a Coil of One-Inch Standard Iron Pipe and Condensing Water on the Outside of the Same. Pressure of Steam 60 Pounds per Square Inch above the Atmosphere.

Number of Test.	Exposed Surface in Square Feet.	Difference of Temperature of Steam and Condensing Water. Degrees Fahr.	Heat Transmitted per Degree of Difference Steam and Water. B. T. U.	Heat Transmitted per Square Foot per Hour per Degree of Difference of Temperature. B. T. U.	Averages of Heat Transmitted per Square Foot per Hour per Degree Difference of Temperature. B. T. U.
1	9.36	226.8	832.2	266.7	265.3
2	9.07	226.8	805.7	266.5	
3	9.36	227.7	820.1	262.8	
4	9.36	207.	837.5	268.4	268.7
5	9.06	207.2	807.25	267.3	
6	9.06	207.2	818.2	270.3	
7	9.36	187.4	841.6	269.7	272.3
8	9.36	187.4	845.9	274.9	
9	9.36	167.0	856.4	274.4	
10	9.36	167.6	865.9	277.5	276.6
11	9.12	167.6	844.8	277.9	
12	9.08	146.8	839.3	277.3	
13	9.06	147.2	848.8	281.0	281.4
14	9.21	149.4	878.1	286.0	
15	9.36	126.8	936.0	300.0	
16	9.36	127.2	929.2	297.8	298.9
17	9.36	108.	972.5	311.7	
18	9.36	107.2	977.3	313.9	312.8

A graphical representation of the results of Experiment I. is given in Fig. 2.

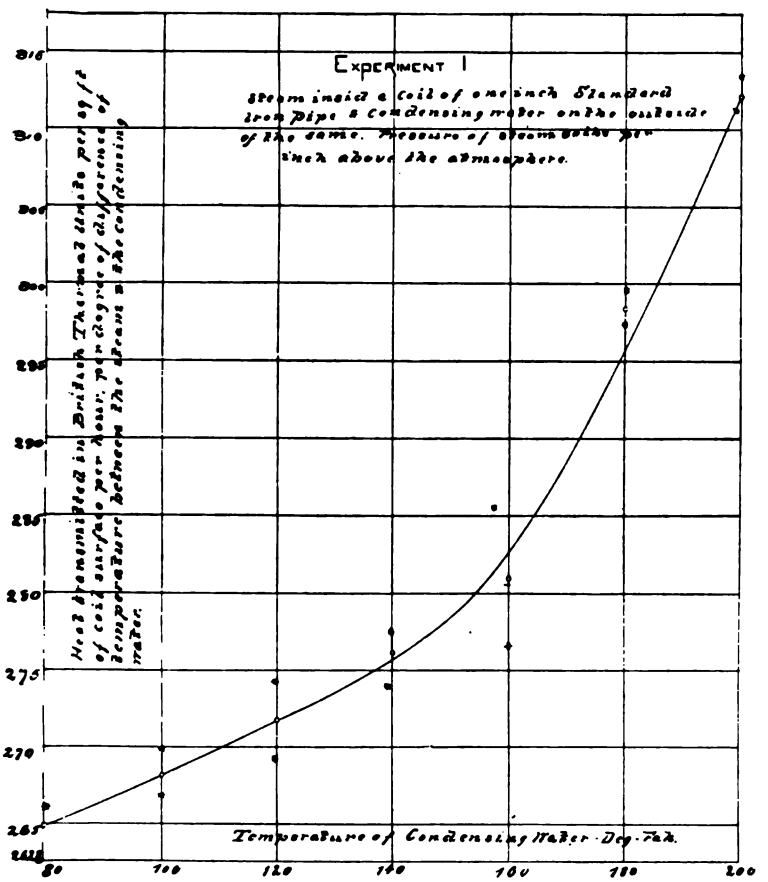
Experiment I
Steam inside a coil of one inch Standard Iron Pipe & Condensing water on the outside of the same. Pressure of steam 10 lbs per inch above the atmosphere.
Heat transmitted in British Thermal Units per sq. ft. of coil surface per hour, per degree of difference of temperature between the steam & the condensing water.
Temperature of Condensing Water - Deg. Fah.
80
100
120
140
160
180
200
270
275
280
285
290
295
300
305
310

FIG. 2.

EXPERIMENT II.

In obtaining the results at 10 pounds pressure, a second coil was used consisting of piping 1½ inches in diameter arranged in 6.5 turns of 16 inches in diameter. This was the only change from the first apparatus described, all the connections being as previously explained. This change was made as the latter coil was better adapted for use in other tests, to be described in subsequent pages. The results obtained with this coil are given in Tables III. and IV.

TABLE III.—DATA TAKEN DURING EXPERIMENT II.

Steam Inside a Coil of 1½-Inch Iron Pipe and Condensing Water on the Outside of the Same. Pressure of Steam 10 Pounds per Square Inch above the Atmosphere.

Number of Test.	Temperature of Condensing Water in Degrees Fahr.	Temperature of Steam at Entrance in Degrees Fahr.	Temperature of Condensed Steam in Degrees Fahr.	Weight of Condensed Steam in Pounds.	Height of Condensing Water in Inches.
1	80.0	276.8	195.4	97.75	60
2	80.4	272.0	186.8	91.0	60
3	81.2	271.0	180.8	87.0	60
4	100.	271.6	178.2	81.5	60
5	100.2	271.2	180.6	82.25	60
6	119.6	272.4	183.8	74.0	60
7	119.6	270.6	179.1	74.0	60
8	140.0	270.2	192.0	65.5	60
9	139.6	272.0	208.0	69.75	65
10	160.0	271.8	198.6	58.5	60
11	159.4	271.2	209.8	57.5	60
12	180.0	271.8	196.8	50.0	60
13	180.0	270.4	190.4	46.5	60

TABLE IV.—RESULTS OF EXPERIMENT II.

Steam Inside a Coil of 1½-Inch Iron Pipe and Condensing Water on the Outside of the Same. Steam Pressure 10 Pounds per Square Inch above the Atmosphere.

Number of Test.	Exposed Surface in Square Feet.	Difference Between Temperature of the Steam and Condensing Water. Degrees Fahr.	Heat Transmitted per Degree of Difference of Steam and Water. B. T. U.	Heat Transmitted per Hour per Square Foot per Degree of Difference of Temperature. B. T. U.	Averages of Heat Transmitted per Hour per Square Foot per Degree Difference of Temperature. B. T. U.
1	13.8	159.4	618.1	134.3	127.9
2	13.8	159.0	586.7	127.5	
3	13.8	158.2	560.8	121.9	
4	13.8	139.4	597.06	129.8	130.4
5	13.8	139.2	602.7	131.0	
6	13.8	119.8	627.6	136.7	136.9
7	13.8	119.8	630.8	137.1	
8	13.8	99.4	664.2	143.9	144.9
9	14.25	99.8	694.3	146.0	
10	13.8	79.4	738.4	160.5	157.7
11	13.8	80.0	712.16	154.8	
12	13.8	59.4	843.5	175.7	173.8
13	13.8	59.4	790.5	171.9	

A graphical representation of the results of Experiment II. is given in Fig. 3.

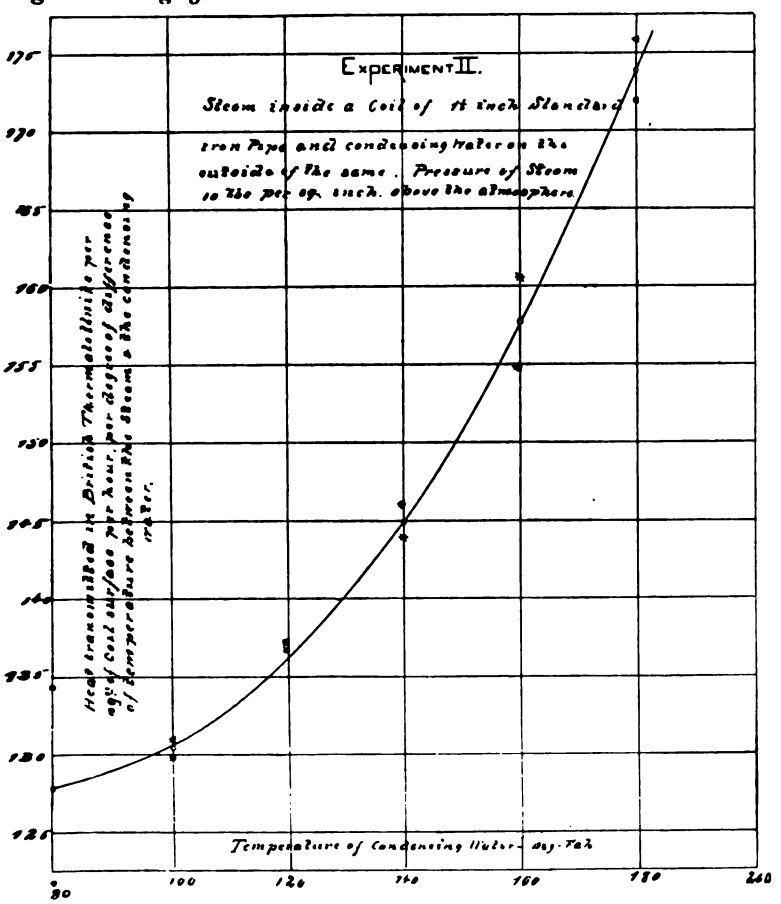
Experiment II.
Steam inside a Coil of 1¼ inch Standard
iron Pipe and condensing Water on the
outside of the same. Pressure of Steam
10 lbs per sq. inch above the atmosphere.
Heat transmitted in British Thermal Units per
sq. ft. of Coil surface per hour, per degree of difference
of temperature between the Steam & the condensing
water.
Temperature of condensing Water — deg. Fah.
90
100
120
140
160
180
240

FIG. 3.

EXPERIMENT III.

A series of experiments was made in which the relative positions of the steam and condensing water were reversed.

The coil used in the second experiment was encased in a cast-iron cylinder, shown in the drawing at S, Fig. 4, and the condensing water was pumped through it from the tank B. The temperature of the condensing water was regulated in the tank B. The steam

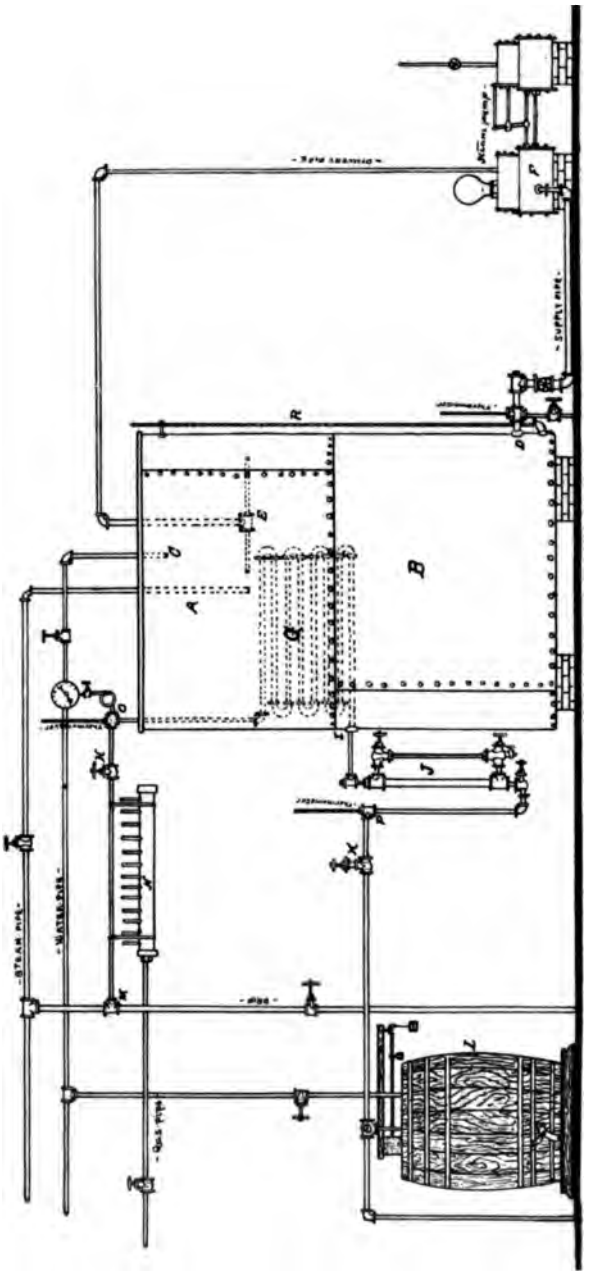
A
B
C
D
E
F
G
H
J
K
L
M
N
O
P
R
X
STEAM PIPE
WATER PIPE
GAS PIPE
SUPPLY PIPE

FIG. 4.

was admitted from the boiler into the cylinder at H, under a pressure of 10 pounds above the atmosphere, the same precautions being taken as in the first two experiments to prevent the carrying over of moisture in the steam. A water-glass J was arranged in the

TABLE V.—DATA TAKEN DURING EXPERIMENT III.

Steam Outside of a Coil of 1¼-Inch Iron Pipe and Condensing Water on the Inside of the Pipe. Pressure of Steam 10 Pounds per Square Inch above the Atmosphere.

Number of Test.	Temperature of Condensing Water in Degrees Fahr.	Temperature of Steam at Entrance in Degrees Fahr.	Temperature of Condensed Steam in Degrees Fahr.	Weight of Condensed Steam in Pounds.
1	80.0	269.0	189.6	121.0
2	80.0	271.8	186.0	121.75
3	80.0	271.2	181.4	118.0
4	100.1	271.2	201.0	127.0
5	100.0	271.6	196.6	116.75
6	100.0	272.2	202.6	120.75
7	118.6	272.0	208.4	123.25
8	119.8	271.6	210.2	114.5
9	120.1	273.2	211.0	117.75
10	119.8	273.0	218.8	121.25
11	140.6	269.6	214.6	105.25
12	140.2	272.0	218.0	100.5
13	140.4	272.6	218.0	100.5
14	140.2	272.8	218.2	103.0
15	160.0	271.2	222.4	82.0
16	160.0	271.2	223.6	82.0
17	159.0	271.6	221.6	85.5
18	160.5	272.0	221.8	84.75
19	180.0	269.6	225.0	61.0
20	179.5	270.8	225.6	60.75
21	180.0	271.4	224.6	65.5
22	180.0	271.6	224.8	64.75

bottom of the cylinder S, and the condensed steam was drawn off into a weighing barrel L as fast as it accumulated, without changing the pressure in the cylinder.

In order to prevent radiation from the cylinder into the air, it was carefully encased in 2 inches of hair felt. This thoroughly insulated it, a test for radiation showing that the correction for the same could be neglected.

The necessary readings were taken for the temperature of the condensing water, at the entrance R of the coil, for that of the condensed steam, at the exit P from the water-glass, and for the temperature and pressure of the steam at O, its entrance into the

TABLE VI.—RESULTS OF EXPERIMENT III.

Steam Outside of a Coil of 1¼-Inch Iron Pipe and Condensing Water on the Inside of the Pipe. Coil Surface 11.4 Square Feet. Pressure of Steam 10 Pounds per Square Inch above the Atmosphere.

Number of Test.	Difference of Temperature of Steam and Condensing Water in Degrees Fahr.	Heat Units Transmitted per Degree of Difference of Steam and Water. B. T. U.	Heat Transmitted per Degree of Difference of Temperature per Square Foot per Hour. B. T. U.	Average of Heat Transmitted per Degree of Difference of Temperature per Square Foot per Hour. B. T. U.
1	159.4	763.7	200.1	200.2
2	159.4	775.1	203.9	
3	159.4	747.6	196.7	
4	139.3	911.4	239.9	229.5
5	139.4	840.2	221.1	
6	139.4	864.8	227.6	
7	120.8	1012.7	266.5	259.6
8	119.6	948.3	249.5	
9	119.3	977.6	257.3	
10	119.6	1006.3	264.8	
11	98.8	1049.5	276.2	267.4
12	99.2	997.8	262.1	
13	99.0	999.1	262.9	
14	99.2	1020.5	268.5	
15	79.4	1010.2	265.8	270.7
16	79.4	1008.9	265.5	
17	80.4	1041.2	274.	
18	78.9	1051.8	276.8	
19	59.4	1002.8	263.9	270.2
20	59.9	988.6	260.1	
21	59.4	1074.7	282.8	
22	59.4	1040.7	273.9	

cylinder. The details of the arrangement are shown in the drawing, A being the steam pipe for heating the condensing water, C the water pipe arranged for the regulation of the temperature of the condensing water. The water was pumped from the tank at D and returned through E by the pump F.

The results of the tests are given in Tables V. and VI.

A graphical representation of the results of Experiment III. is given in Fig. 5.

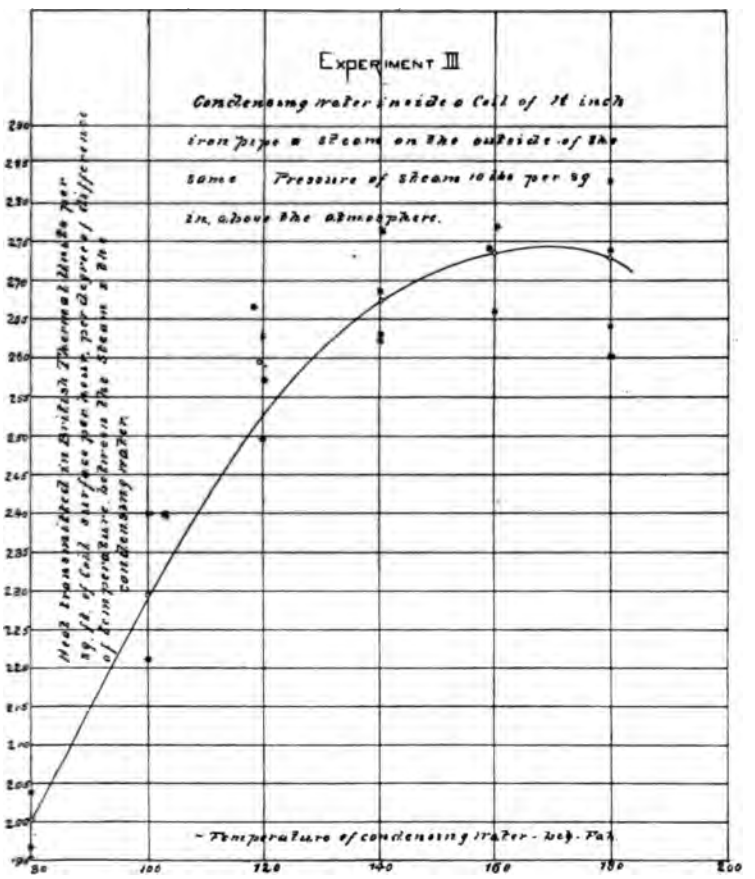
Experiment III
Condensing water inside a Coil of ¾ inch
iron pipe & steam on the outside of the
same Pressure of steam 10 lbs per sq
in. above the atmosphere.
Heat transmitted in British Thermal Units per
sq. ft. of Coil surface per hour per degree of difference
of temperature between the steam & the
condensing water.
Temperature of condensing water - deg. Fah.

FIG. 5.

The curves drawn from the results of Experiments I. and II., in which the steam is inside the coils, indicate that the heat transmitted, for a degree of difference between the temperatures of the steam and the condensing water, increased as the temperature of the condensing water increased.

Experiment III., in which the steam is outside the coil, does not furnish a regular increasing law as in the preceding cases. It

will be observed on comparing Figs. 2, 3, and 5 that the total amount of heat transmitted per square foot per hour per degree difference of temperature increases in general with an increase of temperature of the condensing water, but it appears that the rate does not increase as fast at the higher temperatures in the case where the steam is on the outside of coil as it does with steam on the inside of the same, and in one case there is a slight decrease.

The amount transmitted is much larger with the steam on the outside of the coil than with steam inside the coil. This may be explained in part by the fact that the condensing water when inside the coils flows over the surface of conduction very rapidly, and is more efficient for cooling than when contained in a tank outside of the coil.

This result is in accordance with that found by Mr. Thomas Craddock (D. K. Clark, p. 461,) at an early period, which indicated that the rate of cooling by transmission of heat through metallic surfaces was almost wholly dependent on the rate of circulation of the cooling medium over the surface to be cooled.

In addition to the series of tests made on the coil at 10 pounds pressure of steam outside of the coil, a second series of tests was made with steam at 60 pounds pressure in the interior of the coil, for the purpose of comparison with Experiment I., in which a coil 1 inch in diameter was employed.

Tables VII. and VIII. give the data and results derived from these experiments. Figure 6 gives a graphical representation of the results of this latter experiment, and shows a higher efficiency for all temperatures beyond 140° Fahr., for the helical coil of 1½-inch pipe, while below that value the loop coil of 1-inch pipe used in Experiment I. is more efficient. This is probably due to the different stages of corrosion of the two coils, and also to the fact that the surfaces were not alike as regards smoothness. However, by referring to the curve in Fig. 6 and the tables, it is seen that the general law derived from the previous experiments is applicable to the later one—*i. e.*, the rate of transmission per degree of differ-

TABLE VII.—DATA TAKEN DURING EXPERIMENT IV.

Steam Inside a Coil of 1½-Inch Iron Pipe and Condensing Water on the Outside of the Same. Pressure of Steam 60 Pounds per Square Inch above the Atmosphere.

Number of Test.	Temperature of Condensing Water in Degrees Fahr.	Temperature of Steam at Entrance in Degrees Fahr.	Temperature of Condensed Steam in Degrees Fahr.	Weight of Condensed Steam in Pounds.	Height of Condensing Water in Inches.
1	105.5	310.5	286.5	243.25	60.0
2	101.0	311.5	287.2	250.65	60.0
3	119.2	309.5	276.7	230.65	60.0
4	120.	309.5	283.0	234.00	61.1
5	140.	311.0	290.0	232.00	60.0
6	139.2	313.0	282.7	230.65	60.0
7	160.	310.0	283.5	226.30	60.0
8	160.	310.0	290.0	231.25	60.0
9	185.2	311.2	286.8	219.00	60.8
10	180.2	310.2	287.0	216.65	60.9
11	202.2	308.0	285.0	219.00	60.7
12	202.2	310.8	293.2	224.30	60.0

TABLE VIII.—RESULTS OF EXPERIMENT IV.

Steam Inside a Coil of 1½-Inch Iron Pipe and Condensing Water on the Outside of the Same. Pressure of Steam 60 Pounds per Square Inch above the Atmosphere.

Number of Test.	Exposed Surface in Square Feet.	Difference of Temperature of Steam and Condensing Water in Degrees Fahr.	Heat Transmitted per Degree of Difference of Steam and Water. B. T. U.	Heat Transmitted per Square Foot per Hour per Degree of Difference of Temperature. B. T. U.	Averages of Heat Transmitted per Square Foot per Hour per Degree Difference of Temperature. B. T. U.
1	13.96	201.7	832.4	238.5	239.3
2	13.96	206.2	838.5	240.2	
3	13.96	188.0	855.1	245.1	247.2
4	14.004	187.2	872.6	249.2	
5	13.96	166.7	956.9	278.3	275.6
6	13.96	168.0	952.9	273.0	
7	13.96	147.2	1063.5	304.8	305.8
8	13.96	147.2	1073.3	307.5	
9	13.992	122.0	1238.6	354.0	348.9
10	13.996	127.0	1203.4	343.9	
11	13.988	105.0	1439.6	411.7	419.1
12	13.96	105.0	1463.6	426.5	

ence between the temperatures of the condensing water and the steam increases with the increase of temperature of the condensing water, while the actual amount of steam condensed per hour decreases.

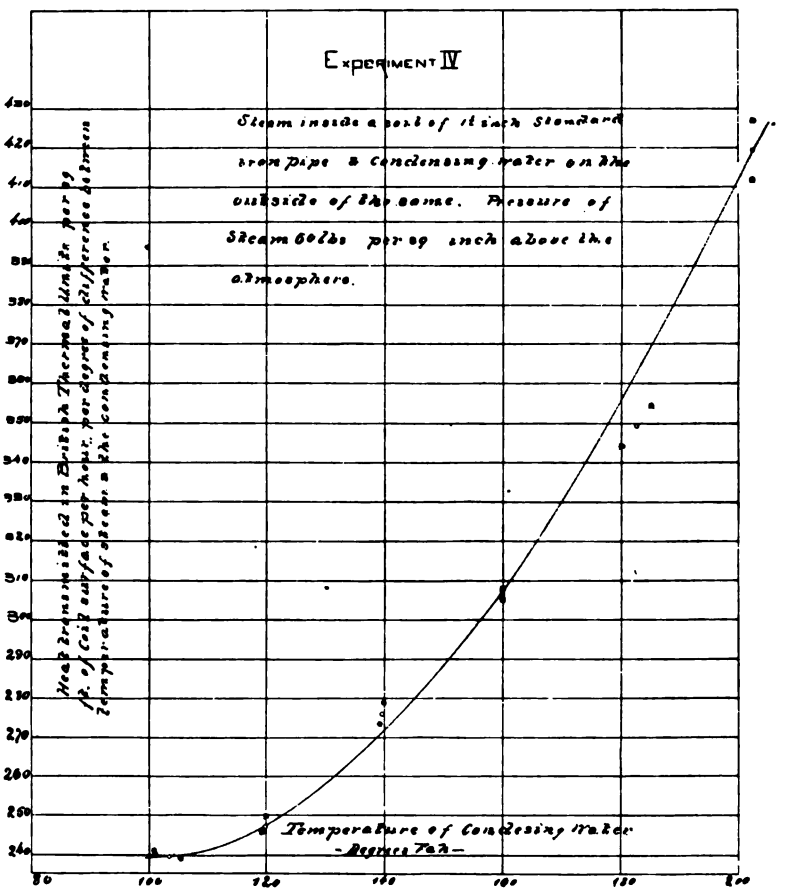
Experiment IV
Steam inside a pipe 8 inch Standard
iron pipe & Condensing water on the
outside of the same. Pressure of
Steam 60 lbs per sq inch above the
atmosphere.
Heat transmitted in British Thermal Units per hour
per sq. ft. of pipe surface per hour, per degree of difference between
Temperature of steam & the condensing water.
Temperature of Condensing Water
- Degrees Fah -

FIG. 6.

The results of the investigation as a whole go to prove that while the general law of transmission as determined by earlier experimenters is confirmed, the values obtained by them are too great for ordinary conditions of surfaces.

THE ANALYSIS OF LUBRICATING OILS CONTAINING "BLOWN" RAPE-SEED AND "BLOWN" COTTON-SEED OILS.*

BY PROF. THOMAS B. STILLMAN, PH. D.

RAPE-SEED oil has long been the standard oil in Europe for lubrication. Its constancy of viscosity at varying temperatures, its non-liability to acidity as compared with other seed oils, and its low cold test, unite in producing the results required of a good lubricant. It, however, is no exception to the rule that vegetable and animal oils suffer partial decomposition when subjected to high temperature produced by friction, with a result that fatty acids are liberated and corrosion of bearings produced.

The substitution of mineral oils in varying proportions with rape-seed oil has reduced this tendency, this reduction being determined by the percentages of mineral oil present, as the latter liberates no free acids.

It is a peculiar fact, however, that a mineral oil alone does not give as satisfactory results in lubrication (especially cylinder lubrication†) as does a mixture of mineral and vegetable or mineral and animal oils, one of the primary causes being that the viscosity of mineral oils rapidly diminishes at high temperatures, whereas the reduction of viscosity of vegetable and animal oils is very much less.

If it were not for this peculiarity between these two classes of oils, mineral lubricating oils could easily supplant (on the score of cheapness) all other oils used in lubrication.

The admixture of oils then being required for the better class of lubricants, it follows that in England, where rape-seed oil has been the standard, its use should be continued in compounded oils.

The proportion of rape-seed oil added to mineral oil varies from 5 to 20 per cent. Where the mineral oil is a clear paraffin oil

* From the *Journal of the American Chemical Society*, Vol. XV.

† *The Railroad and Engineering Journal*, 64, 73-126.

20 per cent. of the seed oil is used; where the mineral oil is a dark, heavy oil, 5 per cent. is generally added.

The separation and estimation of the rape-seed oil in these mixtures present no difficulty to the analytical chemist when no other seed oil is present, since the saponification of the seed oil, the separation of the fatty acids, and recognition of the same are a part of the usual chemical work of this character. The recognition of the constituents of a mixed lubricating oil by analysis is a very different problem from giving a formula by which the mixture can be made. This is evidenced as follows:

Suppose the analysis shows

Rape-seed oil, 20 per cent.
Paraffin oil, 80 per cent.

Paraffin oil varies in specific gravity from 0.875 to 0.921, and it is essential to include in the report of the analysis not only the amount of the paraffin oil but also the gravity, since paraffin oil of gravity 0.875 is a very different product from that of 0.921 gravity, the former selling at 7½ cents and the latter at 23 cents per gallon. This determination can be made by taking the gravity of the original mixed oil (0.912), then knowing by analysis that 20 per cent. is rape-seed oil (gravity 0.918), the gravity of the 80 per cent. of paraffin oil is easily calculated. Thus:

x — specific gravity of rape-seed oil (0.918).
y — specific gravity of paraffin oil.
x — 20 per cent., or $\frac{1}{5}$.
y — 80 per cent., or $\frac{4}{5}$.

Then $\frac{1}{5}x + \frac{4}{5}y = 0.912$.
$0.183 + \frac{4}{5}y = 0.912$.
$\frac{4}{5}y = 0.729$.
$y = 0.910$.

The mixture being composed, therefore, of
Paraffin oil (sp. gr. 0.910), 80 per cent.
Rape-seed oil (sp. gr. 0.918), 20 per cent.

The direct determination by analysis from the ether solution of the mineral oil in the mixture does not give an oil of the same specific gravity as the mineral had before it was mixed with the seed oil. This can be accounted for by the volatilization of a portion of the lighter hydrocarbons of the mineral oil when the ether is expelled during the analysis. For this reason the determination of the percentage of seed oil and the calculation of the mineral oil offers less liability to failure than finding the mineral oil directly.

The introduction of "blown" rape-seed oil instead of the normal rape-seed oil complicates the investigation and renders the use of the formula above given valueless. Rape-seed oil has a gravity of 0.915 to 0.920. Rape-seed oil "blown" has a gravity of from 0.930 to 0.960.

Two difficulties are immediately presented: (1) The chemical analysis does not indicate whether the rape-seed oil is "blown" or not. (2) The use of the formula given without the correct gravity of the "blown" oil would give false results regarding the paraffin oil. To overcome this difficulty some synthetical work is required.

Suppose the specific gravity of the mixed oil is 0.922 and the analysis shows 20 per cent. of rape-seed oil. It will be necessary then to produce a mixture in these proportions that will duplicate the original sample. A check upon this will be the viscosity of the original sample as compared with the one to be made by formula. Thus:

The original oil has a gravity of 0.922, contains (by analysis) 20 per cent. of rape-seed oil, and has a viscosity at 100° Fahr. of 335 seconds (Pennslyvania Railroad Pipette).

First.—Make a mixture of paraffin oil (sp. gr. 0.910) generally used in this character of lubricant, 80 per cent., and rape-seed oil ("unblown") 20 per cent. The viscosity is 165 seconds, showing that this mixture cannot be used in place of the original oil.

Second.—Make a mixture of paraffin oil (sp. gr. 0.910) and rape-seed oil (partially blown sp. gr. 0.930) in the same proportions as above. The resulting viscosity is 267 seconds, showing that the compound is still lacking in viscosity.

Third.—Make a mixture of paraffin oil (sp. gr. 0.910) 80 parts, and rape-seed oil, "blown," (sp. gr. 0.960), 20 parts. The viscosity is 332 seconds.

This now fulfills the conditions required and the synthetical sample agrees with the original in gravity, composition, and viscosity.

The use of "blown" rape-seed oil is being gradually replaced by "blown" cotton-seed oil. The latter, which has had but a limited use in lubrication, owing to its liability to acidity, has been greatly improved by this process of "blowing," which is nearly complete oxidation of the oil under comparatively high temperature.

This largely prevents the occurrence of the acidity in the oil, and thus the main objection to its use in lubrication disappears. It is much cheaper than rape-seed oil, since it costs 40 cents per gallon, to 70 cents per gallon for the latter. The chemical reactions of the two oils are very similar, and careful analytical work is required that the chemist be not misled.

The following table of comparisons will indicate this:

SPECIFIC GRAVITY.

Cotton-seed oil	0.920 to 0.925
Rape-seed oil	0.915 to 0.920
"Blown" cotton-seed oil	0.930 to 0.960
"Blown" rape-seed oil	0.930 to 0 960

VISCOSITY (PENNSYLVANIA RAILROAD PIPETTE) AT 100° FAHR.

	Seconds.
Cotton-seed oil (sp. gr. 0.925)	165
Rape-seed oil (sp. gr. 0.918)	210
"Blown" cotton-seed oil (sp. gr. 0.960)	2,143
"Blown" rape-seed oil (sp. gr. 0.960)	2,160

HEIDENREICH'S TEST.

	Before Stirring.	After Stirring.
Cotton-seed oil	Faint reddish brown.	Brown.
Rape-seed oil	Yellow-brown.	Brown.

MASSIE'S TEST.

Cotton-seed oil	Orange-red
Rape-seed oil	Orange.

IODINE ABSORPTION.

Cotton-seed oil	104 to 114
"Blown" cotton-seed oil	93 to 103
Rape-seed oil	102 to 108
"Blown" rape-seed oil	94 to 100

In the comparison of the two oils, when not mixed with a mineral oil, the above tests can be used. The conditions are altered, however, when either one or both are so mixed, since these tests apply only to the pure oils and not to those reduced with large percentages of mineral oil. After the separation of the seed oil from the mineral oil by saponification the identification of the seed oil depends upon the reactions of the fatty acids obtained, and a careful examination and comparison of these reactions show that the melting points have the greatest difference and thus become a means of recognition.

Thus, the fatty acids from rape-seed oil melt at 20° C., and from cotton-seed oil at 30° C. Hence, if upon analysis of a lubricating oil under above conditions, the fatty acids obtained show a melting point of 20° C. the seed oil can be pronounced rape-seed oil.

If the melting point is between these limits, say 23° C., the seed oils are present in a mixture, the proportions of which can be determined by the following formula:

w_1 — proportion of rape-seed oil.
w_2 — proportion of cotton-seed oil.
w_3 — weight of mixture (20 per cent.).
t_1 — temperature of melting point fatty acids of rape-seed oil.
t_2 — temperature of melting point fatty acids of cotton-seed oil.
t_3 — temperature of melting point of mixed fatty acids.

Then $w_1 = w_3 \frac{t_3 - t_2}{t_1 - t_2}$.

$w_2 = w_3 \frac{t_3 - t_1}{t_2 - t_1}$.

Inserting the values:

$w_1 = 20 \frac{23-30}{20-30} = 14$ per cent.

$w_2 = 20 \frac{23-20}{30-20} = 6$ per cent.

Or,

Paraffin oil	80 per cent.
Rape-seed oil	14 " "
Cotton-seed oil	6 " "
Total	100 " "

By synthetical work upon these proportions, with comparison of viscosities of the sample submitted with the product, the result will be not only a correct analysis, but a working formula can be given by which a manufacturer can duplicate the original oil.

EXTRACTS FROM THE ENGINEERING PRESS.

THE PROSPECTS FOR OUR SHIPYARDS.

"THE outlook this year at the shipyards of our Great Lakes is not unpromising, if we may judge by the contracts that are reported to have been made at places between Buffalo and Duluth. The large and costly steamer which is nearly completed at Cleveland for the Northern line passenger service, will be the first vessel of its class to enter the waters of Lake Erie this year, and there are others of equal size and power that will come after it. At several of our Atlantic ports, also, the prospects for the shipyards are better than they were a year ago. We have especially encouraging reports from Bath, where, among other craft to be launched this year, is a steel sailing vessel, the first vessel of the kind ever built at Bath."—*The Engineer.*

LARGE STEAM PIPES.*

"Eleven years ago it became necessary for me to construct several thousand feet of 20-inch steam pipe, besides considerable lengths of 15 and 12-inch sizes, and the satisfactory results obtained lead me to describe the methods of construction. It was decided to make a mild steel riveted pipe, with die-forged flanges of the same material, and rivet and calk the flanges. For riveting the pipe an Allen pneumatic riveter was used; and as the extreme reach of the arms of the machine used was about 70 inches, the courses were made of that length, netting between roundabout seams 68 inches. I had observed that the greatest difficulty with riveted pipe was keeping the roundabout seams tight, and this was evidently caused by water accumulating about these seams on the bottom of the pipe when steam was off; when steam was readmitted these small accumulations of water caused unequal expansion, as the portions covered by them heated much slower than the unprotected surfaces, and in this way leaks were started in the roundabout seams at the bottom. To avoid this, each course was made the frustum of a

* Extract from a paper presented by Charles H. Manning, Superintendent of the Amoskeag Manufacturing Co., Manchester, N. H., at the New York meeting (December, 1839) of the American Society of Mechanical Engineers, and published in *The Engineer.*

cone, thus bringing the laps all in one direction, and by placing the large end of the cone uphill and giving the pipe sufficient grade, it was easy to keep it free of water at all times, and this has been entirely successful. All large pipes are liable to water-hammer, and a hammer that would completely wreck a cast-iron pipe or split a lap-welded pipe from end to end will have little or no effect on the riveted pipe, except to strain the joints of the longitudinal seams; but I have never known a riveted pipe to give out.

"Some makers of large riveted pipe use very unsightly cast-iron flanges, which they seldom succeed in keeping tight for any length of time, and the cost is fully as much as with the wrought flanges."

A LARGE RIEHLÉ TESTING MACHINE.

"A LARGE Riehlé screw testing machine is now being erected at the College of Civil Engineering of Cornell University. It is complete in all of its appointments, and has a capacity of 400,000 pounds for tension and compression, and of 100,000 pounds for transverse strain."—*The Engineering Record.*

WELDLESS CHAINS.

"A BAD link or bad weld in the ordinary iron chain may cause very serious consequences. The weld is in fact a permanent source of danger, as it is impossible to be sure that it is perfectly made.

"For a long time, experiments have been conducted in various countries for the purpose of doing away with welding in the manufacture of chains. This problem has been solved by M. Oury, who is in charge of the Marine Arsenal at Cherbourg. The Oury chain is of the same form as the ordinary iron chain. It is manufactured from soft steel bars of a regular cruciform section, which are heated and run through nicking machines. The bars are then returned to the furnace, and passed through a series of stamping hammers provided with matrices, which produce a weldless chain of the ordinary form. If the chain is to be stayed, the stemples are then put in. Under test these chains have given some remarkable results, a $\frac{7}{10}$-inch chain having shown a breaking strain of 53,736 pounds, or 68,106 pounds per square inch."—*Revue Industrielle.*

STANDARD TIME IN ITALY.

"'CENTRAL EUROPEAN TIME,' the standard time in use in Austria and Germany, being that of the fifteenth degree east of Greenwich, has been introduced on the Italian railroads. Heretofore, all Italian railroads except those in Sicily have used the time of Rome, which is quite central. The hours of the day will be numbered from 1 to 24, beginning with midnight, whereas they formerly began with the sunset."—*American Engineer.*

ATHLETICS.

AT the annual election of the Athletic Association, held on January 9, 1894, the following officers for the ensuing year were elected: William H. Corbett, '95, President; Lattimore Carter, '95, Vice-President; Carrol Miller, '96, Secretary; C. P. Paulding, '95, Treasurer. R. E. Hall, '95, T. E. Jewell, '95, and F. R. Chambers, '96, were elected members of the Executive Board.

An election for Captain of the Athletic Team for the annual Field Day with Rutgers College resulted in the selection of Ed. Kemble, '95.

It was decided not to support a base-ball team for the coming season.

FOOT-BALL.

OWING to the late issue of the October number of the INDICATOR, an account of the past foot-ball season was published in that number. As to the ranking of Stevens in the Middle States League: Stevens defeated Rutgers, and Lafayette, Stevens. The Rutgers team was disbanded early in the season, and the Rutgers-Lafayette game being on this account forfeited to Lafayette, Lafayette takes first place, Stevens second, and Rutgers third.

The team owes much to its Captain, Frank Coyne, and to Messrs. De Hart, Marshall, and Hall, all of '90, who aided in coaching.

By the graduation of the Class of '94 the team will lose Coyne and Kellogg, ends; Gallaher, center, and MacCord and Fielder, behind the line. Another loss to be regretted is that of McIlwain, guard, who has left college. The material from which these places must be filled will need a great deal of development; and we have reason to hope that in this particular the new Captain, Kemble, will be as successful as was Coyne.

LACROSSE.

There is reason to believe that during the coming season more interest in lacrosse will be taken by the general public than heretofore. There is talk of Cornell joining the League, and it is probable that at the convention, which is to be held in Philadelphia early in February, a formal application will be made. Caspar R. Whitney has signified his intention of taking the game up, so the merits of lacrosse are certain to receive more general recognition.

Last year lacrosse interests were somewhat hampered by the presence of a base-ball team in the field. Owing to the recent action of the Athletic Association this will not be the case this year, and we hope that our base-ball enthusiasts will turn their attention to lacrosse.

Morris Kellogg is Captain of the team and R. E. Hall Manager. Gymnasium work will not be required as much as heretofore, and it is probable that no training table will be supported. The team is, of course, somewhat weakened by the graduation of the Class of '93, but Captain Kellogg expects to put a strong team in the field, and we have the brightest prospects for a successful season.

FIELD GAMES.

The policy of the Athletic Association in electing at this time a field captain for the coming season is to be commended. The results of the contests at the joint field day with Rutgers serve to show that a thorough preparation on the part of Stevens athletes will be necessary if they are to carry off the honors this season.

CANE SPREE.

The challenge to a cane rush sent by the Sophomores to the Freshmen instituted a squabble, the complications of which do not deserve mention, and the results of which we have been unable to discover.

AN EXTRACT FROM THE SECRETARY'S REPORT, STEVENS ATHLETIC ASSOCIATION.

In reviewing the situation for the past year we note that the Association has made a number of important moves in new directions, some of which have fulfilled our best hopes and others fallen far short of anticipation. One of the most pleasing features was the co-operation of the Glee and Banjo Clubs, showing a unity of interest among our associations such as every college should cherish. The financial aid resulting was almost invaluable, and the precedent established should become a fixed policy in our yearly progress. The rejuvenated attempt to support both a lacrosse and base-ball team proved as fruitless as might be anticipated, the division of interest in so small an institution reacting unfavorably to the welfare of both. Our brilliant conception to solicit our alumni for financial aid was a dismal failure, and aside from the valuable experience gained, which future secretaries may profit by, little can be said in favor of the scheme.

Briefly summed up, we have $12 actual expense and about ten hours of labor, rewarded by two lonesome $5 checks from as many patriots among about 500 supposed lovers of their Alma Mater.

The joint Field Day with Rutgers affords our athletes an unusually fine opportunity for exciting contests, and, although the nature of the opportunity was not appreciated early enough last spring to induce preliminary practice, and the results were therefore disappointing to Stevens, yet the arrangement has merit, warranting permanent athletic and financial success.

We are at last in a foot-ball league of appropriate calibre and circuit, and the season's work offers much encouragement for its future prosperity and maintenance. The main subject of regret is the old story of lack of interest and financial support by the undergraduate body which must ever be the mainspring of our Association, and as we surrender our guardianship to our successors it is with the earnest hope that they may be able to enthuse a little more loyalty into the students of the Institute.

Respectfully submitted,

WILLIAM H. CORBETT.

TREASURER'S REPORT, STEVENS ATHLETIC ASSOCIATION.

Receipts.		*Expenditures.*	
By Balance Received from H. D. Lawton	$147.61	To The H. H. Kiffe Company	$182.87
" Dues and Initiation Fees	315.50	" Photos and Frames	7.00
" Proceeds of Hoboken Concert,	125.05	" Expenses of Lacrosse Team	282.00
" Subscriptions	57.31	" Expenses of Foot-ball Team	243.95
" Gate Receipts	317.75	" Printing and Advertising	37.50
" Lehigh and J. H. U. for Lacrosse Banner	10.00	" Smithson	77.54
" Locker Rentals	1.00	" Expenses of Spring Games	15 88
" Dividend from I. A. A.	123.33	" Expenses of Stevens-Rutgers Games	28.07
" Cop at Grove Street, who was absent	1.00	" Guarantees	91.40
" Amount advanced for Expense of Stevens-Rutgers Games	5.75	" Lacrosse Banner	15.00
		" Sundries	34.19
Total Receipts	$1,104.30	Total Expenditures	$1,015.40
		Balance on Hand	88.90
			$1,104.30

Due Intercollegiate Tennis Association	$10.00
Due H. H. Kiffe Company	116.70
	$126.70
Balance on hand	88.90
Leaving deficit	$37.80
Due Field Manager	17.02
	$54.82

LATTIMORE CARTER,
Treasurer.

INSTITUTE NOTES.

A CORRECTION.—Notwithstanding the care taken in proof-reading with the Biographical Sketch of President Morton, printed by the Portrait Committee in 1892, two typographical errors were overlooked, which, as they destroy the correct meaning of their contexts, all who possess this book are asked to correct.

On page 126, third line from the foot, "beautiful" should be *bountiful.*

On page 130, in the last line of the second verse, "hero" should be *here.*

The latter correction can be easily made by inserting a cross-bar in the letter o, and scratching out with a knife the lower right-hand quadrant of the same letter.

"Pasters" containing the word "bountiful" will be furnished to any one applying at this office, to correct the other misprint.

THE MIDWINTER meeting of the Alumni Association is announced for Tuesday, February 20, at 8 o'clock, in the lecture-room at Hoboken. The Executive Committee have arranged for unusual social attractions.

By circular letter sent out in December, the Executive Committee sought an expression of opinion by the members as to the desirability of having a dinner at one of the New York hotels, and continuing the meeting thereafter. The majority of the responses were adverse to this plan, which was therefore abandoned.

PROFESSOR RIESENBERGER has so far recovered from his severe illness that he expects to return on February 1 from Lakewood, where he has been recuperating for several weeks, and to at once resume his duties.

AT THE time of the Engineering Congress at Chicago, in August, 1893, there was organized the Society for the Promotion of Engineering Education. The officers elected for the first year were: De Volsen Wood, Stevens Institute of Technology, President; S. B. Christy, University of California, George F. Swain, Massachusetts Institute of Technology, Vice-Presidents; J. B. Johnson, Washington University, Secretary; Storm Bull, University of Wisconsin, Treasurer; and twenty-one prominent educators from the leading engineering institutions of the country were chosen as members of the Council.

Great interest has been manifested by teachers of engineering in this new organization, which aims to bring about more harmonious practices and standards, and to consider and report upon many questions of importance to them.

The Society has just published the *Proceedings of the Educational Section of the World's Engineering Congress*, which can be obtained from either the Secretary or Treasurer. The price is $2 if bound in paper, $2.50 if bound in cloth.

THE *American Journal of Science*, Vol. XLVII., January, 1894, contains an elaborate paper by Professor Mayer, entitled "Researches in Acoustics, Paper No. 9," containing:

1. *The Law connecting the Pitch of a Sound with the Duration of its Residual Sensation.*

2. *The Smallest Consonant Intervals among Simple Tones.*

3. *The Durations of the Residual Sonorous Sensations as deduced from the Smallest Consonant Intervals among Simple Tones.*

Professor Mayer describes with his accustomed minuteness the methods and apparatus employed in the researches, and shows numerous illustrations of the instruments experimented with.

Nineteen years ago he published in the same journal "Paper No. 6," of "Researches in Acoustics," containing "an account of his attempts to establish the law connecting the pitch of a sound with the duration of its residual sensations."

"The law given in that paper was the expression of the results of the first experiments, extending through several octaves, ever made on the duration of sonorous sensations."

Reference is made to a long series of experiments made in 1875, at the author's request, by Madame Ema Seiler, who was noted for her ability to analyze composite sounds, the results of which he claimed in his paper of 1875 were worthy to form the basis of a physiological law.

In his recent paper he states "that there is a physiological law which gives the relation between the pitch of a sound and the duration of its residual sensation as shown by the numerous experiments contained in this paper. But those published in 1874 and 1875 sufficed to establish that fact, yet these experiments have never been repeated by physiologists."

"I have waited nineteen years, in the hope that others would make similar experiments, so that the combination of the results of various experimenters would give an expression of the law which might be regarded as general, and accepted as expressing the average residual sensations of sounds."

Dr. Rudolph Koenig, of Paris, in whose laboratory is his "grand tonometre," giving the frequency of all sounds from 16 to 21,845 complete vibrations per second, made for Professor Mayer, in 1893, a series of experiments to determine the smallest consonant intervals among sounds below $U\ T_8$ in pitch; and the results, given in the experimenter's own

words, are included in Professor Mayer's paper, which closes with the following statement: "In explanation of the facts and laws given in this paper I have no hypothesis to offer. It appears to me that the present condition of our knowledge of audition demands that we should ascertain more facts relating to it before we frame hypotheses on the mechanism and action of the apparatus of hearing."

PROFESSOR MACCORD has recently applied a new principle to the cutting out of elliptical mats suitable for mounting pictures or for other purposes. By his design, the ellipse is cut by a knife attached to an arm out of a plane that is made to rotate, the plane and arm having a uniform motion. The bridle rod is at every instant normal to the curve, and the blade of the knife, being attached at right angles to the length of the rod, presents its cutting edge at all times in the direction of the curve.

Another recent invention of Professor MacCord's is an elliptic lathe for the production of elliptical cylinders of any desired length or form of elliptical cross-section. It can be made to serve as an ordinary circular lathe or to turn out lengths of uniform section throughout, or lengths either tapering or varying from circular to elliptical section.

Application has been made for patents covering this lathe, which will be assigned to Messrs. Pratt and Whitney, who have secured exclusive rights thereunder.

STEVENS INSTITUTE was well represented in the proceedings of the meeting of the Mechanical Section of the American Association for the Advancement of Science, at Madison, Wis.

Professor Webb presented a paper on "Economical Steam Consumption."

Professor Jacobus had one on "Experimental Determination of the Quickness of Action of a Shaft Governor," one describing "An Accurate Method of Measuring Heavy Liquid Pressures," and a third on "An Improved Oven for Determining the Sensitiveness of Automatic Sprinklers."

An abstract of the thesis of Messrs. Hupfel, Griswold, and Mackenzie, of '93, on a Test of the New York Hygeia Ice-Making Plant was also read.

Short abstracts of all the above have been published in *American Machinist* (January 11), and the thesis is printed at length in this number of the INDICATOR.

THE NEW dynamo room looks very attractive since it has been put in thorough order. As this new building cuts off most of the light on the east side of the shop, the metal lathes that were there have been moved to the west side, where they can be used to advantage. All the machines in the shop have recently been supplied with gas burners on jointed pipes, so that the light can be thrown on any part of the work, for close inspection.

Engineering News of December 28, 1893, makes mention of an important improvement in planimeters devised by Professor Jacobus.

It consists in the substitution for the ordinary tracing point of a glass plate having two hair lines cut on its underside at right angles.

In tracing a diagram the point of intersection of these lines is kept on the line to be traced. The ordinary point has a tendency to make a slight groove in the paper, so that, on a second tracing, the point tends to follow in the groove left by the first. Again, where repeated tracings have to be made, the point tends to obliterate the line.

The improved form of tracer is open to no such objections, and it can be used in the evening, while the ordinary planimeter cannot, on account of the shadows cast by the tracing point.

PROFESSOR WOOD, in a short paper appearing in "Popular Astronomy," discusses the question: "Does the Luminiferous Ether Serve as a Medium for the Transmission of the Force of Gravitation?" and maintains that gravity cannot be propagated by the luminiferous ether, inasmuch as the velocity of a wave in the latter approximates 186,300 miles per second, while the force of gravitation, as found by La Place, if propagated by an elastic medium, must have a velocity exceeding a hundred million times that of light. Hence, if gravity is propagated by an ether, it must be one peculiar to itself, which may be called the "gravitation ether."

PROFESSOR BRISTOL'S automatic recording instruments for pressure, temperature, and electricity, and his steel belt lacing, have been granted an award by the World's Columbian Exposition.

THE ENGINEERING NEWS PUBLISHING COMPANY, N. Y., offered three prizes for the best graduating theses submitted by students graduating from any Americen engineering school in 1893. The first prize was of $75, the second $50, and the third prize was of $25.

Charles T. Bayless, '93, of Louisville, Ky., and Arthur E. Merkel, '93, of New York, graduates of Stevens, received honorable mention for their thesis on "Garbage Cremation in America."

This offer of prizes is again renewed for 1894, and a special prize of $100 is added, to be given for the best post-graduate thesis. Not more than three theses can be submitted from any one institution. They are examined without knowledge of the authors or college, but must be accompanied by sealed letters giving title, author, college, address, etc.

PROFESSOR WOOD'S article on "Integrity of the Interstellar Medium," which first appeared in *Science*, has been reprinted by several other journals.

THE SIXTH EDITION of Professor Wood's "Thermodynamics" is nearly exhausted, and he is now preparing another edition.

MR. RICHARD STEVENS was married to Miss Elizabeth Callendar Stevens, daughter of Mr. and Mrs. Francis B. Stevens, at Saint Paul's Church, Hoboken, on November 11, 1893.

INSTITUTE PERSONALS.

It is our endeavor to notice under this heading such items of news affecting graduates of the Institute as may interest their classmates and friends among the Alumni. We are indebted to a few members for regular or frequent contributions of items, and wish to make it known that the co-operation of all is most desirable, and will be appreciated. MANAGING EDITOR.

'75.

FRANK MACDOWELL LEAVITT was married to Miss Gertrude Mitchell Goodsell at Sag Harbor, Long Island, on November 8, 1893.

'77.

E. P. ROBERTS has organized in Cleveland, O., The Correspondence School of Technology, which announces courses of instruction by correspondence in the following subjects: Applied Electricity, Steam Engineering and Transmission of Power, Civil Engineering, Railroad Engineering, Bridge Engineering, and Architecture.

He is the President, and is Instructor in Applied Electricity, and has associated with him Mr. Oscar Antz, '78, as Instructor in Mechanical Engineering; also other gentlemen technically educated and experienced in their respective specialties. The announcement issued by the School is both comprehensive and explicit.

'78.

OSCAR ANTZ is with the Lake Shore Railway, and is located at Cleveland, O., where he is also associated with E. P. Roberts, '77, in conducting The Correspondence School of Technology. His address is Brainard Block, Cleveland, O.

'82.

WILLIAM E. GIBBS has his office at 111 Liberty Street, New York.

'83.

E. D. ESTRADA is now in the firm of Estrada & Gray, formerly Estrada, Kenyon & Gray, inspecting engineers, 307 Lewis Block, Pittsburg. They have also an office at 515 Ashland Block, Chicago, Ill.

'84.

RICHARD LEE FEARN'S address is 1307 P Street, Washington, D. C.

'86.

EDWARD P. MOWTON has taken up the practice of law, having been admitted to the bar last June. He is with Booraem, Hamilton, Beckett & Ransom, counsellors-at-law, No. 160 Broadway, New York.

EDWARD D. SELF has returned from South America and is taking the supplementary course in mining engineering in the Columbia School of Mines.

'87.

JOHN L. COX is with the Midvale Steel Company, Nicetown, Pa.

M. C. JENKINS is with the Coxe Iron Manufacturing Company, Drifton, Pa.

WILLIAM E. QUIMBY has changed his business address to 59 Liberty Street, New York City.

'89.

CHARLEY T. BENNS was married on January 31 to Miss Martha Adela Halton, at Providence, R. I.

NICKOLAI HILLER was married on November 21 to Miss Howes, of Utica.

'90.

A. C. ATRISTAIN is draughtsman for the Mexican Central Railroad. His house address is 1A de la Merced, No. 22 Va 11, Mexico City, Mexico.

WILLIAM N. CARLTON has removed from 75 to 109 White Building, Buffalo, N. Y.

G. L. TODD is at present in New Rochelle, N. Y.

J. T. WESTCOTT was married on October 3, 1893, to Miss Grace Stevens Raphael, at Ocean Grove, N. J.

WHITLOCK–DRAKE. On Wednesday, January 3, 1894, at Cleveland, O., by Rev. Charles Townsend, Lillian M., daughter of J. M. Drake, Esq., was married to Elliott H. Whitlock.

'91.

L E. ELSON has recently formed the Elson & Brewster Engineering Company, electrical and mechanical engineers and contractors, with an office at 122 Liberty Street, New York.

GEORGE C. HOLBERTON visited the Institute November 28, 1893, and started the same day on an extended Western trip.

ANTHONY KENNEDY and S. L. KNOX are associated as consulting engineers with their office at 735 Drexel Building, Philadelphia, Pa. Mr. Kennedy is also connected with the Hollar Safe and Lock Inspection Company as Chief Engineer.

EDWIN S. LORSCH's present address is 47 East 64th Street, New York.

GEORGE F. SUMMERS, who was Manager of the National Gas Light and Fuel Company, of Chicago, Ill., is now located at the office of the United Gas Improvement Company, No. 813 Drexel Building, N. Y.

'92.

HAROLD B. ATKINS has been placed in charge of the Boston Gas Works as Superintendent by the Pintsch Compressing Company.

NICHOLAS S. HILL, Jr., is in business as a consulting engineer, 203 East German Street, Baltimore, Md. He was formerly Inspecting Engineer for the South Side Rapid Transit Railroad Company, Chicago, Ill.

HENRY W. JACKSON is in the employ of the Consolidated Traction Company, of New Jersey, and is located for the present at their main power-house in Jersey City.

'93.

BANCROFT G. BRAINE is with Thomas Brown, Consulting Engineer for the Otis Elevator Company.

O. G. DALE is draughting for the construction of the plant of the National Sugar Refining Company, Yonkers, N. Y.

FRANK L. PARKER is not in the employ of the Capefair Harbor and Coal Company, as erroneously stated in the July INDICATOR, but has special charge of the mechanical department of *The News and Courier*, Charleston, S. C.

SPECIAL.

A. A. DAL MOLIN, special, is with Richards & Company, importers of chemical apparatus, No. 41 Barclay Street, New York.

BOOK NOTICES.

ACCESSIONS TO THE INSTITUTE LIBRARY, JULY 1, 1893, TO JANUARY 1, 1894.

Books Purchased:

General Index of "The Engineering News."
Specifications and Drawings of Patents, U. S. Patent Office. January, February, March, 1892.
Brick for Street Pavements. By M. D. Burke, C. E.
Comptes Rendus. Tomes, 114 and 115 (1892).
Handbuch der Anorganische Chemie. By D. O. Dammer.
Notes on Recent Researches in Electricity and Magnetism. By J. J. Thompson, M. A.
Chimie Appliquée. By Leon Durand.
Traité Pratique de la Fabrication du Ciment du Portland. By A. Lipowitz.
Guide du Chaufournier. By Emile Lejeune.
Proceedings of the Institution of Civil Engineers. Vols. 112 and 113. London.
Jahrbuch der Chemie for 1892. By Richard Meyer.
Subject Matter Index of Technical and Scientific Periodicals. (Berlin.) By Dr. R. Rieth.
Small Yachts. By C. P. Kunhardt.
A New System of Arithmetic. By John W. Nystrom, C. E.
Elements of Analytical Mechanics. By Peter S. Michie.
A Treatise on Masonry Construction. By Ira O. Baker, C. E.
Modern Framed Structures. By J. B. Johnson, C. E.
Protokol des Vereins Deutscher Portland Cement Fabrikanten.
Die Thermodynamic in der Chemie. By J. J. Van Laar.
Neues Handwörterbuch der Chemie. Bd. VI., Lieferg 8. By Dr. Hermann and Fehling.
Proceedings of the Royal Society. Vols. 52, 53, and 54. London.
Bibliographie de la Technologie Chimique des Fibres Textiles. By M. Jules Garcon.
Industries Chimiques. By M. Duquesnay.
Ciments et Chaux Hydrauliques. By E. Caudlot.
Traité Pratique de Calorimetrie Chimique. By M. Berthelot.
The Steam Engine. By James H. Cotterill.

Annual Report of the Commissioner of Patents. 1892.
Oils, Fats, Waxes, and Manufactured Products. By Alder Wright.
Lehrbuch der Experimental Physik. 4 Vols. By Dr. Adolph Wüllner.
Traité de Photometrie Industrielle. By A. Palaz.
The Art of Casting in Iron. By Simpson Bolland.
International Engineering Congress. 2 Vols. By George W. Melville.
Division of Marine and Naval Engineering. 2 Vols. By George W. Melville.

Books Contributed:

By President Morton. *A Catalogue of Scientific and Technical Journals.* By H. C. Bolton.
By President Morton. *The C. W. Hunt Co.*
By Prof. De Volson Wood. *Thermodynamics, Heat Motors, and Refrigerating Machines.* By De Volson Wood.
By Professor Denton. *A Manual of the Steam Engine.* Vol. II. By R. H. Thurston.
By Professor Richards, Hoboken Academy. *Zeitschrift für das Berg Hütten U. Salinen Wesen.* 7 Vols.
By Professor Richards. *Atlas to the above.* 7 Vols.
By Charles E. Monroe. *Index to Literature of Explosives.* By C. E. Monroe.
By James R. Willett. *Heating and Ventilation of Residences.* By J. R. Willett.
By W. H. Roberts, '93. *Der Portland Cement und seine Anwendungen im Bauwesen.*
By "Railway Age." *Compound Locomotives.* By A. T. Woods.
By Royal Society, New South Wales. *Journal and Proceedings of the Royal Society, N. S. W.*
By Benjamin S. Lyman. *The Great Mesozoic Fault in New Jersey.* By Benjamin S. Lyman.
By S. B. Dod. *Annual Report of the New Jersey State Geologist.* 1892.
By Stevens Indicator. *How to Make Inventions.* By E. P. Thompson, M. E.
By Stevens Indicator. *Alternating Currents of Electricity.* By Gilbert Kapp, C. E.
By Stevens Indicator. *Tips to Inventors.* By Robert Grimshaw, Ph.D.
By Secretary of the Navy. *Report of the Superintendent of the U. S. Naval Observatory.* By Lieut. C. C. Marsh, U. S. N.
By Bureau of Education. *Statistics of Public Libraries of the U. S. and Canada.* By Weston Flint.
By Bureau of Education. *Report of the Commissioner of Education.* 1890.
By Royal Society of Canada. *Transactions of the Royal Society of Canada for 1892.*
By American Institution of Mining Engineers. *Transactions of the American Institute of Mining Engineers.*

By American Railroad Master Mechanics' Association. *Report of Proceedings of the American Railroad Master Mechanics' Association.*

By Smithsonian Institution. *Smithsonian Miscellaneous Collections.* Vol. 34.

By Smithsonian Institution. *Bibliography of Chemistry.* By H. C. Bolton.

By Smithsonian Institution. *Annual Report of Bureau of Ethnology.* 1886–1887. By J. W. Powell.

By Smithsonian Institution. *Bibliography of the Chinookan Languages.* By James C. Pilling.

By Bureau of Equipment. *The American Ephemeris and Nautical Almanac for 1896.* By Simon Newcomb.

By Treasury Department. *Register of U. S. Revenue Marine.*

By International Marine Congress. *International Marine Congress.*

By Massachusetts State Board of Health. *Twenty-fourth Annual Report of Massachusetts State Board of Health.*

By War Department. *Report of the Chief of Ordnance, U. S. Army.* By D. W. Flagler.

By U. S. Commissioner of Labor. *Seventh Annual Report of the Commissioner of Labor.* By Carrol D. Wright.

By U. S. Commissioner of Labor. *Third Special Report of the Commissioner of Labor.*

By U. S. Commissioner of Labor. *The Gothenburgh System of Liquor Traffic.* By E. R. L. Gould, Ph. D.

By Department of the Interior. *The Growth of Industrial Art.* By Hon. Benjamin Butterworth.

By Department of Agriculture. *Report on the Forecasting of Thunderstorms* (1892). By N. B. Conger.

By Department of Agriculture. *Experiment Station Record, March, 1893.*

By Department of Agriculture. *Report for 1891 of the Secretary of Agriculture.*

By Department of Agriculture. *Organization Lists, Agricultural Experiment Stations.*

By Department of Agriculture. *The Climate of Chicago.* By Henry A. Hazen.

By Department of Agriculture. *Report of Chief of Weather Bureau for 1892.* By M. W. Harrington.

By Department of Agriculture. *Certain Climatic Features of the Two Dakotas.* By John P. Finlay.

By Department of State. *Reports of U. S. Commissioners, Paris Exposition, 1889.*

By Department of State. *Sixth Annual Report Interstate Commerce Commission.*

By Corps Engineers, U. S. Army. *Notes on Mitering Lock Gates.* By H. F. Hodges.

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TILDEN FOUNDATIONS.

THE STEVENS INDICATOR.

APRIL

ERRORS OF MEASUREMENTS OF POWER BY THE ENGINE INDICATOR

BY PROF.

THIS subject was investigated [illegible]
of the results was published [illegible]
tion of a paper read before the Society of Naval
Engineers by Mr. David [illegible]
[illegible] Engineering Congress
presented in detail at the meeting
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[illegible] the scale. In the spring
[illegible] tests should be made with steam, as
[illegible] they should be [illegible]
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[illegible] for steam pressures are [illegible]
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[illegible] of a spring is less than the [illegible]
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[illegible] the nominal scales marked on the springs by the

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THE STEVENS INDICATOR.

VOL. XI. APRIL, 1894. No. 2

ERRORS OF MEASUREMENTS OF POWER BY THE STEAM ENGINE INDICATOR.

BY PROF. D. S. JACOBUS.

THIS subject was investigated experimentally, and an abstract of the results was published in the discussion by Professor Denton of a paper read before the Society of Naval Architects and Marine Engineers by Mr. David Smith, Chief Engineer of the U. S. Navy, at the Engineering Congress held at Chicago. The work was presented in detail at the meeting of the American Society of Mechanical Engineers, and will form part of Vol. XV. of their *Transactions*. The object of the present paper is to present the matter in a complete form, and to add details of experiments which have been made since the meeting.

In all accurate testing work of to-day the indicator springs are tested to determine the scale. If the springs are used on a steam cylinder, the tests should be made with steam pressure; if used on an air compressor, they should be made with air pressure; and in the case of water pumps a water pressure should be employed. The scales determined for steam pressures are called the hot scale of the springs. The action of heat tends to weaken the springs, so that the hot scale of a spring is less than the cold scale.

The scales determined by testing the springs often differ considerably from the nominal scales marked on the springs by the

makers, in many cases this variation being as high as 5 per cent. As good practice, however, demands that the true scales as determined by tests, and not the nominal scales, be used, we will not discuss the errors that may be involved by employing the nominal scales, but pass to those which enter if the true scales are used.

Comparative tests of four indicators, attached so as to obtain simultaneous cards from one end of the cylinder of a 7x14-inch horizontal engine running at from 175 to 200 revolutions per minute, showed that the results agreed with each other to within 2 per cent. of the mean effective pressure at one-quarter cut-off, after all corrections were made for variations in the scales of the springs at different heights of the diagram. In these tests the steam pressure averaged about 95 pounds per square inch above atmosphere. The indicators were attached at the two ends of a tee connected to the end of the cylinder, and were reversed in the middle of each test. After every three cards the indicator pistons were removed, and the cylinders and pistons cleaned and oiled. The strings driving the indicator drums were made as short as possible, and wire cord was used to connect them with the parallel motion.

This agreement holds only for indicators in correct adjustment, in which there is but little friction. The friction of an indicator piston should be so small that there will not be over the thickness of a very fine pencil line between the lines obtained for a rising and falling steam pressure in the tests to determine the hot scale of the springs. A leaky piston is much more reliable than one that is too tight a fit. A piston that will fall through the cylinder by its own weight may be too tight, and produce errors incident to undue friction. A correctly fitted piston may also be thrown out of line by the action of the spring, and thus produce excessive friction.

The theory was advanced at the last meeting of the American Society of Mechanical Engineers that the double line shown in many of the tests of indicators is due to what may be called a lag in the spring. That is, if the lines for a rising and falling pressure do not agree with each other, it was suggested that the fault may lie

in the spring itself. In the tests of the springs used in the comparisons which follow, no double lines were shown with a rising and falling pressure when tested with an accurately calibrated gauge.

In these tests, the lag of the gauge itself was determined and allowed for. In the tests of the springs, made through the courtesy of Commodore George W. Melville at the Brooklyn Navy Yard, the lines for a rising and falling pressure agreed to within about one sixty-fourth of an inch. The variation in this case was not accounted for definitely, but it may have been due to the action of inertia in the moving mercury column. The average results, however, for a rising and falling pressure in the tests at the Navy Yard agreed with those obtained by ourselves from diagrams in which there were no double lines.

Special tests, described further on in this paper, show that there was no appreciable lag in the spring, so that it follows that indicators may be made to give the same results with rising and falling steam pressures. If, therefore, there is a difference found between the lines, it should be sought out and eliminated, as the friction which causes this difference may produce an error in the power measurements.

The tests also show that the variation of the weight of the moving parts, within the limits now employed by makers of the standard instruments, does not affect the accuracy of the results obtained by the indicators. To prove this fact in a conclusive way, a weight was attached to the piston of one of the indicators, equal to the weight of the moving parts, including the gravity component of the pencil motion, and it was found that the addition of this weight, which made the mechanism heavier than that in any of the current makes of indicators, did not introduce an error.

The hot scales of the springs were determined as follows: The indicators were subjected to a steam pressure which was measured by a gauge so arranged that it was perfectly cool. The pressure was adjusted to the desired amount, and lines were traced by the indicator pencil. In making a record, the pencil of the indicator

was first raised slowly and gradually released, and a line traced; it was then pressed downward and released gradually, and a second line traced. For indicators in correct adjustment these lines coincided exactly, or so nearly that there was not the thickness of a very fine pencil line between them. The scales derived by the above method were found to agree, as has been already stated, with those determined in tests made at the Brooklyn Navy Yard, in which the indicators were compared directly with a mercury column.

As the scale of an indicator spring varies for different heights of the diagram, it is impossible to say from a simple inspection of the indicator card, and of the results of the tests, which scale should be used to determine the mean effective pressure. The general way we have adopted has been to employ the scale over the range of about the mean forward and the mean back pressure; but, in the present investigation, it was thought advisable to go further, and to employ the scales corresponding to each portion of the diagram.

There may be an error involved in employing scales determined over any particular range of pressure. Thus, in the four indicators that were tested, if the scales had been determined over a range of 100 pounds per square inch above the atmosphere, which was about 20 pounds greater than the initial pressure, the error of so doing would have been as a maximum 3 per cent., or, adding opposite signs, 5 per cent. If the range had been from the atmosphere to the initial pressure, the error would have been, as a maximum, about 1 per cent., or, adding opposite signs, 2 per cent.

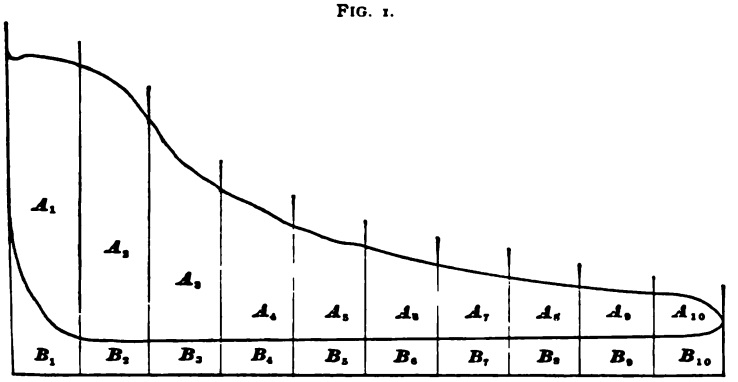
If the scales were determined between the mean forward and the mean back pressure, the error would have been only 1 per cent., adding opposite signs, but this small variation is exceptional, and cases are often met in which the error is greater than this amount.

There is an element of uncertainty which enters in the use of an indicator spring, from the fact that it may not be at precisely the same temperature when employed in power measurements as it attains during the tests to determine the hot scale. This error would tend to affect all indicator springs in the same direction, so that it

does not alter the comparative results shown by different indicators working under the same conditions, but it may be of importance in determining the absolute scales. The total amount of the error is small, and will be made the subject of a future investigation.

The method of correcting for all variations in the scales is as follows:

FIG. 1.



DIVISION OF INDICATOR CARD IN ORDER TO OBTAIN THE EQUIVALENT SCALE CORRECTED FOR ALL VARIATIONS IN THE SCALE OF THE SPRING.

Divide the card by a number of ordinates at equal distances apart, as represented in Fig. 1. Measure the areas A_1, A_2, etc., included between the forward-pressure line and the atmospheric line, and the areas B_1, B_2, etc., between the back-pressure line and the atmospheric line. Multiply each area by the scale corresponding to the average pressure, and let SA be the sum of the areas multiplied by the scales for the forward-pressure line, and SB be the sum of the areas multiplied by the scales for the back-pressure line, then the equivalent scale which the average height of the indicator card should be multiplied by in order to obtain the true mean effective pressure will be [SA–SB] divided by the area of the indicator card.

In calculating the equivalent scales the largest and smallest cards of the set are taken; and, if the scales for these two cards are nearly the same, the scales for intermediate cards may be determined

by interpolation. If the scales are widely different for the largest and smallest cards, that of one or more of the intermediate cards should be calculated. In the present investigation, however, the equivalent scale of the largest and smallest cards of one set were found to agree within the limits of practical error, so that the

TABLE I.—*Comparison of Indicators by Tests at One-quarter Cut-off.*

Corrections made for all variations in the hot scales of the springs.

Number of Comparison.	Number of Test.	Indicator.	Steam Pressure in Pounds per Square Inch above Atmosphere.	Revolutions per Minute.	Weight of Moving Parts in Grammes, Including Gravity Component of Pencil Motion.	Average Mean Height of Card.	Equivalent Scale of Spring.	Mean Effective Pressure in Pounds per Square Inch.	DIFFERENCE IN MEAN EFFECTIVE PRESSURES REFERRED TO INDICATOR OLD A.		
									In Pounds per Square Inch.	In Per Cent. of Total M. E. P.	Equivalent in Height of Card in Inches.
1	1	Old Form of A	104.2	191.3	18 5	.778	58.3	45.4	.....	.....	.....
		New Form of A	104.2	191.3	24.8	.556	80.9	45.0	—0.4	—0 9	.005
2	2	Old Form of A	94.9	190.8	18.5	.675	58.3	39.4	.....	.....	.....
		B	94.9	190.8	30.5	.675	58.2	39 3	—0.1	—0.3	.002
3	3	Old Form of A	90.7	194.8	18.5	.610	58.3	35.6	.....	.....	.....
		C	90.7	194.8	27.0	.738	48.6	35.9	+0.3	+0.8	.005
4	4	Old Form of A	95.0	190.7	18.5	.698	58.3	40.7	.....	.....	.....
		B	95.0	190 7	30.5	.700	58.2	40.7	0	0	0
5	6	Old Form of A	94.3	196.3	18.5	.684	58.3	39.9	.....	.....	.....
		B	94.3	196.3	30.5	.687	58.2	40.0	+0.1	+0.3	.002
6	5	Old A with weighted piston.	94.2	192.1	37.0	.697	58.3	40.6	.....	.....	.....
		B	94.2	192.1	30 5	.697	58.2	40.6	0	0	0
7	7	Old A with loose piston	94 5	192.0	18.0	.681	58 9	40.1	.....	.....	.....
		B	94 5	192.9	30 5	691	58.2	40.2	+0.1	+0.2	.002
8	8	Old A with tight piston	94.2	192.5	19.2	.672	58.3	39.2	.....	.....	.....
		B	94 2	192.5	30.5	.678	58.2	39.4	+0.2	+0.5	.003

In obtaining the equivalent scales of the springs, the cards were divided up into a number of small areas as shown in Fig. 1, and the correct scale was applied to each area in the manner already described.

equivalent scales for the other sets were taken as those corresponding to the average card. The results of the comparisons at one-quarter cut-off, employing the equivalent scales corrected as above for all variations, are given in Table I.; and for scales determined between about the mean forward and the mean back pressure are given in Table II. The four indicators tested are marked in the tables Old Form of A, New Form of A, B, and C.

An examination of Table I., in which corrections are made for all variations of the scales, shows that the greatest difference found between the mean effective pressures for any two indicators was about 1 per cent., which is equivalent to a height measured on the diagram of 0.005 inch. This height, however, represents the error of standardizing the indicator springs, because the

TABLE II.—*Comparison of Indicators by Tests at One-quarter Cut-off.*

Hot scales of springs determined between about the mean forward and the mean back pressures.

Number of Comparison.	Date of Test.	Number of Test.	Indicator Used.	Hot Scale of Spring.	Mean Effective Pressure in Pounds per Square Inch.	Difference in Mean Effective Pressures Referred to Indicator Old A.			Greatest Difference in M. E. P. between any Two Simultaneous Cards.	
						In Pounds per Square Inch.	In Per Cent. of Total M. E. P.	Equivalent in Height of Card in Inches.	In Pounds per Square Inch.	In Per Cent. of Total M. E. P.
1	Oct. 16.	1	Old Form of A	58.8	45.7					
			New Form of A	81.7	45.4	—0.3	0.7	.004	—1.0	2.2
2	Oct. 16.	2	Old Form of A	58.8	33.7					
			B	58.6	39.6	—0.1	0.3	.002	—1.0	2.5
3	Oct. 16.	3	Old Form of A	58.8	35.9					
			C	48.8	36.0	+0.1	0.3	.002	+0.8	2.2
4	Oct. 20.	4	Old Form of A	58.8	41.0					
			B	58.6	41.0	0	0	0	—0.3	0.7
5	Oct. 24.	6	Old Form of A	58.8	40.2					
			B	58.6	40.2	0	0	0	+0.4	1.0
6	Oct. 20.	5	Old A with weighted piston	58.8	41.0					
			B	58.6	40.8	—0.2	0.5	.003	—0.6	1.5
7	Oct. 24.	7	Old A with loose piston	59.0	40.8					
			B	58.6	40.5	—0.3	0.7	.005	—0.7	1.7
8	Oct. 24.	8	Old A with tight piston	58.8	39.6					
			B	58.6	39.7	+0.1	0.3	.002	+0.7	1.8

The steam pressures, revolutions per minute, and weight of moving parts are the same as in Table I.

heights in testing the springs were not measured closer than this amount. It therefore appears that there is no difference shown in the results in Table I., where corrections are made for all variation of scales that may not be caused by errors in standardizing the springs.

The greatest difference between the mean effective pressures for correctly fitted pistons, with scales determined between about the mean forward and the mean back pressure as given in Table II., and the results in which corrections are made for all variations of the scales, as given in Table I., is 0.04 pound per square inch, which is equivalent to 0.007 inch measured on the diagram, and equal to about 1 per cent. of the mean effective pressure.

TABLE III.—*Comparison of Indicators by Tests at One-fortieth Cut-off.*

Hot scales of springs considered to be the same as those determined between about the mean forward and the mean back pressures for one-quarter cut-off. The exact equivalent scales were not determined because the mean effective pressures are so small that the variation of the scales will not affect the results.

Number of Comparison.	Date of Test.	Number of Test.	Indicators Used.	Steam Pressure in Pounds per Square Inch above Atmosphere.	Revolutions per Minute.	Weight of Moving Parts in Grammes, Including Gravity Component of Pencil Motion.	Hot Scale of Spring.	Mean Effective Pressure in Pounds per Square Inch.	Difference in Mean Effective Pressures Referred to Indicator Old A.		Greatest Differences in M. E. P. between any Two Simultaneous Cards.
									Actual in Pounds per Square Inch.	Equivalent in Height of Card in Inches.	
9	Oct. 27.	9	Old Form of A	94.3	180.7	18.5	58.8	7.2	.....	.....	.....
			B	94.3	180.7	30.5	58.6	6.6	—0.6	.010	—0.8
10	Oct. 27	13	Old Form of A	94.3	174.2	18.5	58.8	7.1	.....	.....	.....
			C	94.3	174.2	27.0	48.8	6.9	—0.2	.004	—0.6
11	Oct. 27.	14	Old Form of A	94.8	176.0	18.5	58.8	6.9	.....	.....	.....
			New Form of A	94.8	176.0	24.8	81.7	7.4	+0.5	.006	+0.9
12	Oct. 27.	10	Old A with weighted piston	94.8	176.7	37.0	58.8	7.1	.....	.....	.....
			B	94.8	176.7	30.5	58.6	6.4	—0.7	.012	—0.9
13	Oct. 27.	12	Old A with loose piston	90.7	169.8	18.9	59.9	6.7	.....	.....	.....
			B	90.7	169.8	30.5	58.6	6.5	—0.2	.003	—0.5
14	Oct. 27.	11	Old A with tight piston	93.8	175.5	19.2	58.8	8.0	.....	.....	.....
			B	93.8	175.5	30.5	58.6	6.6	—1.4	.024	—2.0

Comparisons Nos. 1 to 5 are for indicators with ordinarily fitted pistons that were in proper adjustment, as shown in the tests to determine the hot scales.

In comparison No. 6 a weight was attached to the piston of the Old Form of A indicator equal to the weight of the moving parts, including the gravity component of the pencil motion; the addition of this weight, as previously stated, did not introduce an error.

Comparison No. 7 gives the result of a tight piston in the Old Form of A indicator. This piston would fall through the cylinder of the indicator by its own weight, when all oil was removed; but, in the tests to determine the hot scale, the distance between the lines, on pressing the pencil up and down, was about one sixty-fourth of an inch. The results show that the mean effective pressure is the same as for the correctly fitted piston. This is probably due to the fact that the form of the card is such that the friction tends to pro-

TABLE IV.—*Comparison of Scales Obtained in Tests at the Navy Yard and by Employing Our Own Standard.*

Indicator.	Pressure in Pounds per Square Inch above Atmosphere.	Scale of Diagram in Pounds per Square Inch.		Corresponding Difference in Measuring Diagram in Inches.
		Navy Yard Mercury Column.*	Derived from Gauge Standardized by Weight Device.	
Old A.....	25	57.1	56.8	—.002
Old A.....	50	58.7	58.8	+.002
New A.....	25	78.9	79.4	—.002
New A.....	50	81.4	81.7	+.002
New A.....	100	80.2	80.1	—.001
C.....	25	47.9	47.9	.000
C.....	50	48.7	48.8	+.002
C.....	100	50.0	50.0	.000

* Average results for rising and falling pressures.

duce too high a back-pressure line, as well as too high an expansion line, and the error is thus neutralized. It was to introduce the error of friction, so as to make it conspire to add to the area of the card, that the tests at the short cut-off given in Table III. were projected. The cards taken in making these comparisons gave a loop in the expansion line, so that any friction or lost motion tended to add to the area of the diagram. An examination of this table will show that the discrepancies in the mean heights of the cards are slightly greater than at one-quarter cut-off for all the comparisons. In test No. 14, which is for the tight piston, the effect of

friction is to increase the area of the diagram, as can be seen by examining the loop on cards Nos. 9 and 12, one of which is taken with the ordinarily fitted piston, and the other with the tight piston.

Table IV. gives the results of tests made at the Brooklyn Navy Yard, together with those made by ourselves at the same pressures.

TABLE V.—*Determination of Hot Scales of Indicator Springs. Fifty-one Pounds Pressure per Square Inch.*

TESTS MADE OCTOBER 17, 1893.								TESTS WITH THREE SIZES OF PISTONS IN INDICATOR OLD A.			
Old Form of A Indicator.		New Form A of Indicator.		Indicator B.		Indicator C.					
Card.	Height in Inches.	Card.	Height in Inches.	Card.	Height in Inches.	Card.	Height in Inches.	Date of Test.	Tight Piston.	Loose Piston.	Ordinary Piston.
A.	.870	G.	.625	A.	.875	M.	1.040	Oct. 23.	.865	.855	.865
F.	.865	H.	.625	B.	.875	N.	1.045	Oct. 23.	.870	.850	.865
G.	.865	I.	.625	C.	.870	O.	1.050	Oct. 23.	.805	.850	.865
L.	.865	J.	.625	D.	.870	P.	1.045	Oct. 23.	.860	.855	.865
M.	.865	K.	.620	E.	.870	Q.	1.050	Oct. 24.	.860	.850	.870
R.	.875	L.	.625	F.	.865	R.	1.045	Oct. 24.	.860	.845	.865
								Oct. 24.	.870	.855	.870
								Oct. 24.	.870	.850	.870
Average.	.868		.624		.871		1.046		.865	.851	.867
Scale....	58.8		81.7		58.6		48.8			59.9	

The determinations of the hot scales for the three sizes of pistons for the Old Form of A Indicator were made both before and after the dynamic tests comparing the pistons. As the tight and the ordinarily fitted piston gave heights in the tests for the hot scale which agreed within the errors of observation with the values determined on October 17, the scale obtained on October 17 was adhered to in calculating the mean effective pressures from the indicator cards.

In these tests the indicators were compared directly with a mercury column. The tests at the Navy Yard were made after all our tests had been completed.

The basis of pressure employed by ourselves was the Utica Steam Gauge Company's device, in which a flat plate is held down by a weight over a 1-inch square opening having knife edges; a fluid pressure of oil is made to act under the plate, which will raise

when the pressure in pounds per square inch is equal to the weight holding down the plate. The hot scales were redetermined at intervals during and at the close of the dynamic tests, to make certain that there was no change.

The greatest difference between the average results of the two sets of tests is equivalent to a height on the diagram of .002 inch, which is within the error of duplicate measurements.

TABLE VI.—*Determination of Hot Scales of Indicator Springs.*

Tests to Show that the Springs did not Change During the Time that They were in Use. Fifty-one Pounds Pressure per Square Inch.

OLD FORM OF A INDICATOR.		NEW FORM OF A INDICATOR.		INDICATOR C.	
Date.	Height in Inches.	Date.	Height in Inches.	Date.	Height in Inches.
Nov. 8.	.870	Nov. 8.	.620	Nov. 8.	1.045
Nov. 8.	.870	Nov. 8.	.620	Nov. 8.	1.045
Nov. 8.	.865	Nov. 8.	.620	Nov. 8.	1.050
Nov. 8.	.870	Nov. 9.	.630		
Nov. 9.	.870	Nov. 9.	.630		
Nov. 9.	.870	Nov. 9.	.630		
Nov. 9.	.870				
Average...	.869		.625		1.047

The scales of Old and New A and of C are shown by the above to have remained unaltered during the tests. The scale of Indicator B could not be determined at the time the above tests were made, because the cylinder had been removed from it and made to fit over a special tight piston. The comparative tests of Old A and Indicator B in ordinary condition that were made before each special test show, however, that there was no change in the scale of Indicator B.

A gauge was compared with the Utica company's weight device and carried to the Navy Yard, together with the indicators. The corrected readings of the gauge agreed with the Navy Yard standard.

SPECIAL TESTS SHOWING THAT INDICATORS IN CORRECT ADJUSTMENT WILL GIVE THE SAME RESULTS FOR RISING AND FALLING PRESSURES.

To determine the exact facts regarding the possibility of a lag in the springs of the indicators, special tests were made after the meeting. The first set of tests consisted in applying a dead weight to the piston of an indicator, and obtaining the lines for increasing and decreasing loads. To do this the indicator was held in a frame with the drum downward, and a rod was made to press against the

TABLE VII.—*Tests of Indicators at Measurements in Detail for a Given Pressure, Brooklyn Navy Yard.*

Heights in inches corresponding to 50 pounds per square inch above the atmosphere.

Number of Card.	Indicator Old A.	Indicator New A.	Indicator C.
1	.855	.615	1.030
2	.850	.615	1.030
3	.850	.615	1.020
4	.855	.610	1.030
Average	.852	.614	1.027
Scale	58.7	81.4	48.7
Heights in inches corresponding to scales determined by the Utica company's weight device	.850	.612	1.025
Difference in height on diagram between our own and the Navy Yard tests.	.002	.002	.002

piston, which was fitted with a special piece to hold the end of the rod in a central position. The rod was attached to a yoke at its upper end, which passed downward at each side of the frame. A pan for weights was attached to the yoke. The weight was thus made to hang, freely, directly from the center of the piston, and compressed the spring, while the latter was held in the same position it occupied during the tests with steam pressure. These tests showed that there were no double lines produced with increas-

ing and decreasing loads, so that the lag due to the spring itself was less than could be appreciated in indicator measurements.

Tests were made with the spring cold, and also with the spring heated by steam.

A second series of tests was made by connecting two indicators to the indicator-testing device so that both were acted on by the same pressure. A line was taken with both indicators for

TABLE VIII.—*Observations in Detail for One Comparative Test.*

New Form of A Indicator and Old Form of A Indicator. Pistons of indicators in ordinary condition. Test No. 1, Cut-off = ¼. October 16, 1893.

No. of Card.	Steam Pressure in Pounds per Square Inch above Atmosphere.	Revolutions per Minute.	INDICATOR NEW A. SCALE = 81.7.		INDICATOR OLD A. SCALE = 58.8.		Difference between M. E. P. of Simultaneous Cards.
			Mean Height of Card in Inches.	Mean Effective Pressure in Pounds per Square Inch.	Mean Height of Card in Inches.	Mean Effective Pressure in Pounds per Square Inch.	
1.....	104	192	.538	44.0	.742	43.6	+0.4
2.....	104	190	.550	44.9	.770	45.3	—0.4
3.....	104	189	.563	46.0	.766	45.0	+1.0
4	103	202	.571	46.6	.791	46.5	+0.1
5	108	190	.567	46.3	.799	47.0	—0.7
6.....	103	192	.554	45.3	.783	46.0	—0.7
7.....	103	185	.551	45.0	.771	45.3	—0.3
8.....	106	190	.567	46.3	.793	46.6	—0.3
9	101	191	.538	44.0	.765	45.0	—1.0
10. ... , .	106	192	.563	46.0	.791	46.5	—0.5
11.	106	193	.567	46.3	.792	46.6	—0.3
12. .. .	103	190	.547	44.7	.774	45.5	—0.8
Average...	104.2	191.3	.556	45.4	.778	45.7	—0.3

a rising pressure at 40 pounds per square inch, and the cock to one of the indicators was then turned so as to shut off the steam. The pressure was then raised to about 80 pounds, so that one of the indicators was subjected to this pressure, whereas the other, which was shut off, was not. The pressure was then gradually diminished until the gauge registered 40 pounds, when it was corrected for a slight lag, and lines were taken with both instruments.

There was no double line for either indicator. The indicator which was not subjected to over 40 pounds pressure, so that both lines were for a rising pressure, therefore showed that the amount allowed for the lag of the gauge was correct, and the indicator which was subjected to both a rising and falling pressure showed that no double line was produced from this cause.

A third series of tests was made in the following manner: An indicator was first subjected to a high pressure, and a line

TABLE IX.

INDICATOR OLD A.—*Calculation of the Equivalent Scale Corrected for All Variation in the Hot Scale of the Spring. Largest Card of Set.*

Division of Card.	Area.	Mean Height.	Corresponding Scale.	Area by Scale.	Division of Card.	Area.	Mean Height.	Corresponding Scale.	Area by Scale.
A_1	0.64	1.73	58.2	37.25	B_1	0.06	0.16	56.8	3.41
A_2	0.56	1.51	58.3	32.65	B_2	0.02	0.05	"	1.14
A_3	0.46	1.24	58.5	26.91	B_3	0.01	0.03	"	0.57
A_4	0.35	0.94	58.7	20.54	B_4	0.01	0.03	"	0.57
A_5	0.29	0.78	58.8	17.05	B_5	0.01	0.03	"	0.57
A_6	0.25	0.68	58.8	14.70	B_6	0.01	0.03	"	0.57
A_7	0.21	0.57	57.9	12.16	B_7	0.01	0.03	"	0.57
A_8	0.19	0.51	57.4	10.91	B_8	0.01	0.03	"	0.57
A_9	0.15	0.40	56.8	8.52	B_9	0.02	0.05	"	1.14
A_{10}	0.11	0.30	56.8	6.25	B_{10}	0.03	0.08	"	1.70
Totals..	3.21			186.94		0.19			10.81

Equivalent scale = (186.94 — 10.81) + (3.21 — 0.19) = 58.3.

traced. The pressure was then diminished to a certain reading on the gauge, and a second line taken. The pressure was then preserved at a constant figure, and the indicator cock was turned and the atmospheric line traced. The indicator cock was then opened, and a line traced at the constant pressure registered by the gauge. These lines, which were for a rising and falling pressure,

agreed with each other. As the gauge reading was not altered between the time that the lines were taken, the effect of lag in the gauge was eliminated. On opening the indicator cock, to obtain the line for a rising pressure, the pressure increased suddenly; and, to make sure that this did not affect the result, tests were made, in which a valve was placed between the indicator cock and the steam reservoir, so that the pressure could be raised very slowly, as well as lowered very slowly. The lines for rising and falling pressures also agreed in this case.

TABLE X.

INDICATOR OLD A.—*Calculation of the Equivalent Scale Corrected for All Variation in the Hot Scale of the Spring. Smallest Card of Set.*

Division of Card.	Area.	Mean Height.	Corresponding Scale.	Area by Scale.	Division of Card.	Area.	Mean Height.	Corresponding Scale.	Area by Scale.
A_1	0.44	1.19	58.5	25.74	B_1	0.07	0.19	56.8	3.98
A_2	0.42	1.13	58.6	24.61	B_2	0.01	0.03	"	0.57
A_3	0.34	0.92	58.8	19.99	B_3	0.01	0.03	"	0.57
A_4	0.27	0.73	58.8	15.88	B_4	0.01	0.03.	"	0.57
A_5	0.22	0.59	58.0	12.76	B_5	0.01	0.03	"	0.57
A_6	0.18	0.49	57.2	10.30	B_6	0.01	0.03	"	0.57
A_7	0.14	0.38	56.8	7.95	B_7	0.01	0.03	"	0.57
A_8	0.11	0.30	56.8	6.25	B_8	0.02	0.05	"	1.14
A_9	0.09	0.24	56.8	5.11	B_9	0.02	0.05	"	1.14
A_{10}	0.07	0.19	56.8	3.98	B_{10}	0.02	0.05	"	1.14
Totals..	2.28			132.57		0.19			10.82

Equivalent scale = (132.57 — 10.82) + (2.28 — 0.19) = 58.3.

Several springs not used in the comparative tests were experimented on by the above methods, and in no case was there a lag found.

It follows from these tests that there is no appreciable lag in the springs, and that indicators in correct adjustment will give the same results for rising and falling pressures.

METHOD OF MEASURING THE MEAN EFFECTIVE PRESSURES.

The indicator cards were measured by two parties. The first observer measured the area by going around each card twice with an Amsler planimeter, and took a mean of the two readings, provided they agreed to within .02 square inch. If the discrepancy was greater than this, the card was gone over until it fell within the above amount. The results were then tabulated. The second observer worked in a similar way, and prepared a second table, which was compared with the one obtained by the first observer. In general the reading in these tables agreed to within one or two hundredths of a square inch, and, if this was the case, the average value was employed in determining the mean height. In a few cases, however, mistakes in reading gave larger discrepancies, which were corrected before obtaining the mean values.

The planimeters were tested by revolving the tracing point in a circle by means of a radius piece. Each instrument was tested over several sizes of circles. The readings for each revolution were taken for ten consecutive revolutions, and the differences of these readings were found to agree within .03 square inch for an area larger than any of the indicator cards, which demonstrated that the instrument would give concordant readings to within .01 of a square inch. This is a severe test for a planimeter, as any irregularity in the wheel, or want of alignment in the axle, will cause differences in the readings for a given circle, or an alteration in the constant for various sizes of circles and different positions of the fixed point.

Figures 2 to 16 give the indicator cards obtained in the several tests.

Tables V., VI., and VII., give the details of the calibration of the indicator springs. Table VIII. gives the details of one of the comparative tests at one-quarter cut-off. Tables IX. and X. give the calculations of the equivalent scales, corrected for all variations in the hot scale of the spring, for the largest and smallest card taken at about one-quarter cut-off with Indicator Old A.

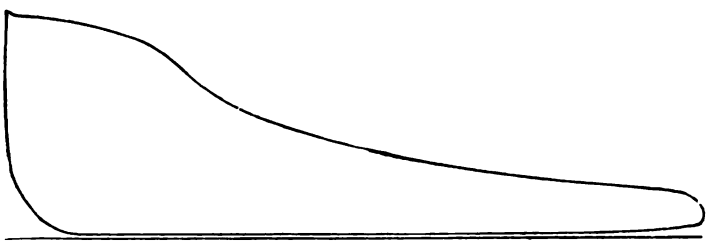


FIG. 2.

New Form of Indicator A.
Test No. 1. Table VIII. Card No. 6.
Revolutions — 192. Steam pressure — 103 pounds.
Equivalent scale corrected for all variations — 80.9 pounds.

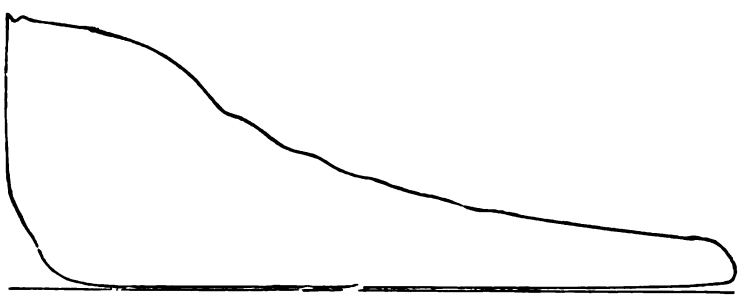


FIG. 3.

Old Form of Indicator A in ordinary condition.
Test No. 2. Card No. 7.
Revolutions — 197. Steam pressure — 96 pounds.
Equivalent scale corrected for all variations — 58.3.

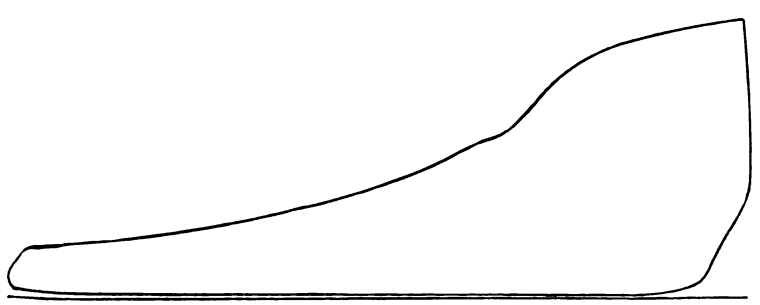


FIG. 4.

Indicator B.
Test No 2. Card No. 7.
Revolutions — 197. Steam pressure — 96 pounds.
Equivalent scale corrected for all variations — 58.2.

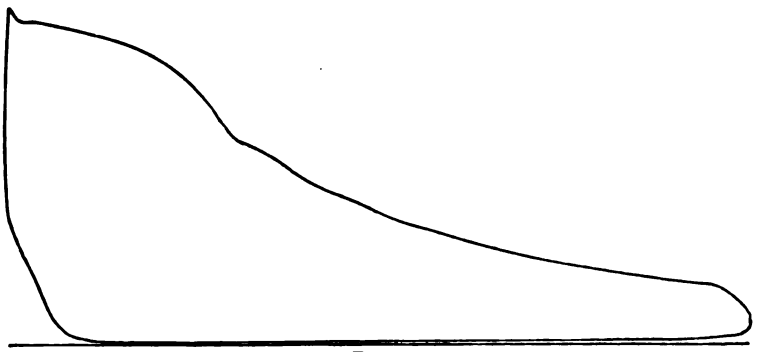


FIG. 5.

Indicator C.
Test No. 3. Card No. 1.
Revolutions — 199. Steam pressure — 95 pounds.
Equivalent scale corrected for all variations — 48.6.

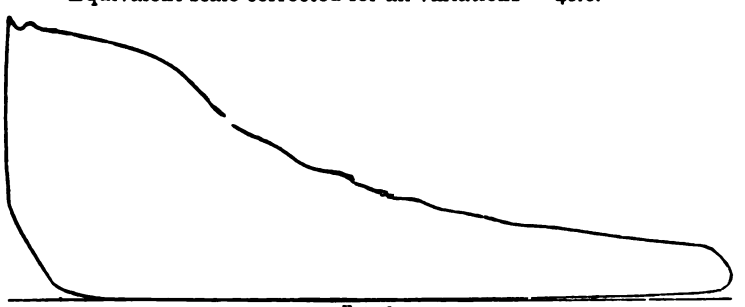


FIG. 6.

Old Form of Indicator A with weight attached to piston.
Test No. 5. Card No. 3.
Revolutions — 189. Steam pressure — 94 pounds.
Equivalent scale corrected for all variations— 58.3 pounds.

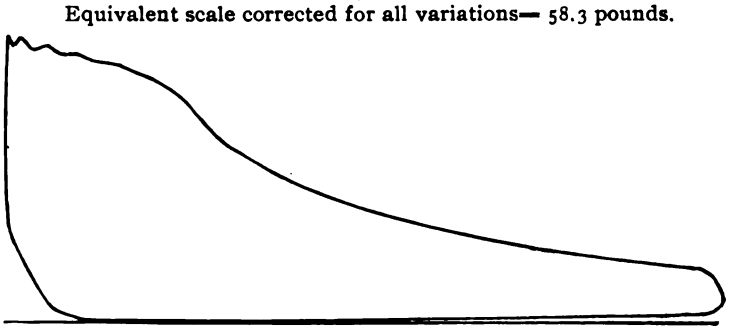


FIG. 7.

Old Form of Indicator A with loose piston.
Test No. 7. Card No. 4.
Revolutions — 196. Steam pressure — 96 pounds.
Equivalent scale corrected for all variations — 58.9.

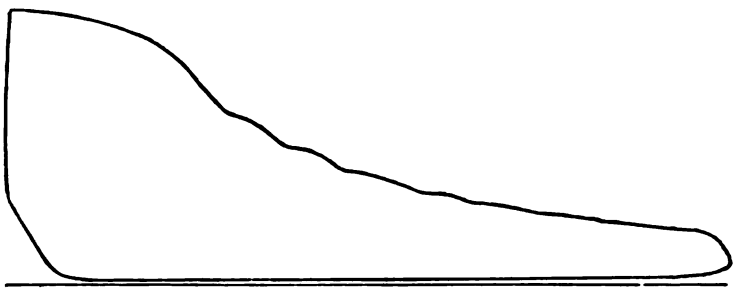


FIG. 8.

Old Form of Indicator A with tight piston.
Test No. 8. Card No. 1.
Revolutions = 195. Steam pressure — 95 pounds.
Equivalent scale corrected for all variations = 58.3 pounds.

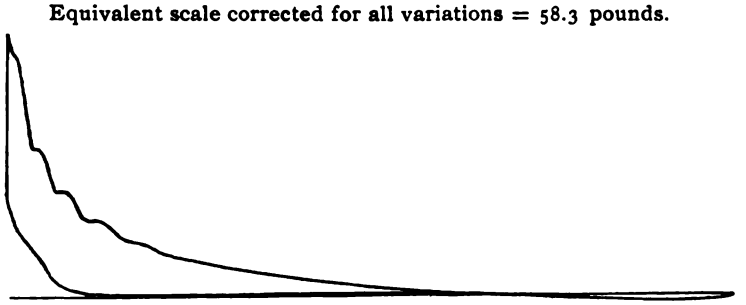


FIG. 9.

Old Form of Indicator A in ordinary condition.
Test No. 9. Card No. 1.
Revolutions = 184. Steam pressure — 93 pounds.
Hot scale of spring = 58.8 pounds.

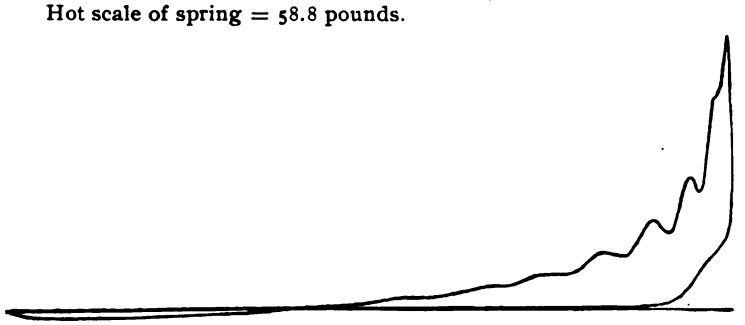


FIG. 10.

Indicator B.
Test No. 9. Card No. 1.
Revolutions — 184. Steam pressure — 93 pounds.
Hot scale of spring — 58.6 pounds.

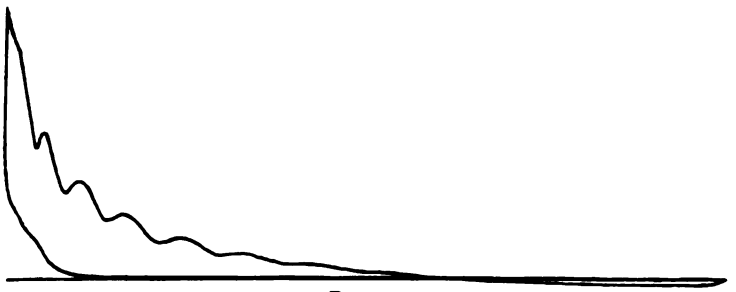


FIG. 11.

Old Form of Indicator A with weight attached to piston.
Test No. 10. Card No. 6.
Revolutions — 178. Steam pressure — 96 pounds.
Hot scale of spring — 58.8 pounds.

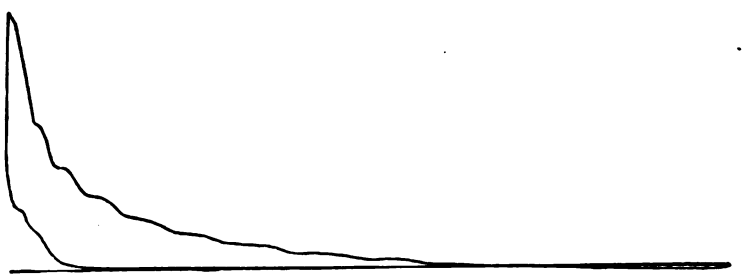


FIG. 12.

Old Form of Indicator A with tight piston.
Test No. 11. Card No. 2.
Revolutions — 176. Steam pressure — 93 pounds.
Hot scale of spring — 58.8 pounds.

FIG. 13.

Old Form of Indicator A with loose piston.
Test No. 12. Card No. 6.
Revolutions — 170. Steam pressure — 92 pounds.
Hot scale of spring — 59.9 pounds.

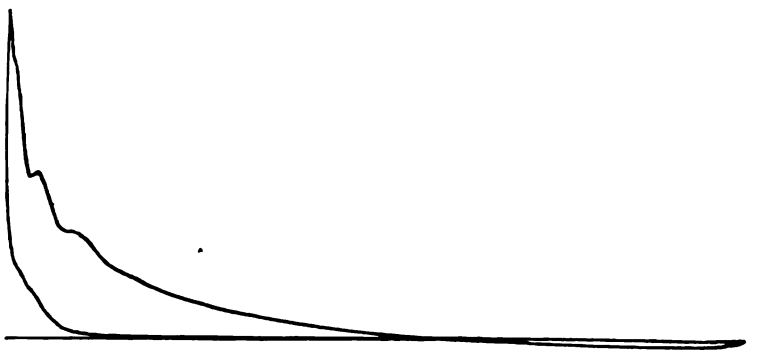


FIG. 14.

Indicator C.
Test No. 13. Card No. 1.
Revolutions — 176. Steam pressure — 94 pounds.
Hot scale of spring — 48.8 pounds.

FIG. 15.

New Form of Indicator A.
Test No. 14. Card No. 6.
Revolutions — 176. Steam pressure — 94 pounds.
Hot scale of spring — 81.7 pounds.

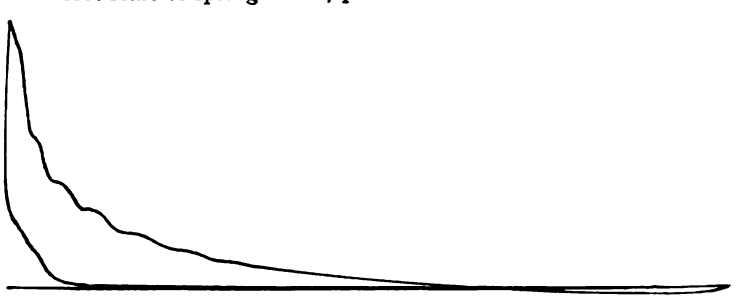


FIG. 16.

Old Form of Indicator A in ordinary condition.
Test No. 14. Card No. 3.
Revolutions — 176. Steam pressure — 97 pounds.
Hot scale of spring — 58.8 pounds.

LECTURE NOTES ON ENGINEERING PRACTICE.

BY COLEMAN SELLERS, E. D.

PERSONAL CONDUCT.

IT is of paramount importance that young men aiming to be engineers in the broadest sense of the word should, with their scientific education, cultivate habits of deportment that will make them distinguished as gentlemen. The gentleman I have in my mind may not be pictured in words to my satisfaction. He certainly has nothing to distinguish him from his fellow-workmen as repulsive to those socially below him. He must feel at home with all classes of men and be attractive to all, high or low. He must inspire confidence by keeping down his own personality. He must not be egotistical; he must, above all things else, be just—just to his employers, just to those who work for him. He must be firm in his convictions, but have moral courage enough to enable him to own to errors in his work or in his judgment when he has discovered such errors or had them pointed out to him. If he aims to get at the truth, he will care for nothing else. You will be obliged to build up, each for himself, a reputation for reliability and for stability.

Those men who have risen to great prominence as engineers, from low estate with limited educational advantages, have won their way by being ready at all times to do not only their whole duty, but to do very much more than is demanded of them. He who stands on his dignity and measures his work by the remuneration he obtains at the moment; he who does little because he considers himself underpaid and not appreciated, is very apt to be distrusted, if he meets with no worse treatment.

My advice holds good when the situation warrants your best exertions.

Sir Edwin Arnold, in his Birmingham address, quoted the "Ahensa," the doing no injury, like the golden rule of Christ, as the last word of Hafiz in his Persian verse:

> "Do no one wrong, then do what thou wilt,
> My statutes recognize no other guilt."

It may be quite out of the exact line of engineering practice to treat of ethical subjects, but as I have had to work my way in the struggle of life against great odds, and am old enough to advise you, I would fail in my duty if I did not urge you, each one to do your best in all your efforts, winning confidence by doing no one wrong.

VALUE OF PRACTICE IN MATHEMATICS AND IN USE OF EXACT EXPRESSIONS.

Many men have become distinguished in original research who have attained their distinction as engineers without having had the opportunities offered by technical schools like the Stevens Institute of Technology; but, from the fact that they have succeeded, it must not be inferred that their course was an easier one, or the road a better one to lead to the desired end. The fact that Michael Farraday was not a professed mathematician might, in his case, have been to his advantage in one respect, as he was compelled to rely upon the clear mental picture formed of every operation in physics resulting from his experiments, and from this mental picture of what he conceived to be going on with matter, whether ponderable or imponderable, he drew conclusions from the experiments that led him to theorize. Had he been possessed of the faculty as well as the knowledge inherent in a professed mathematician, he could have worked more rapidly, because he could have used symbols to represent each one of the separate conditions of each problem, and those symbols could have been grouped in equational form, from

which a rational conclusion would have been reached by ordinary algebraical process. Without this knowledge, however, Farraday had some limited advantage in the fact that he probably made fewer mistakes. Those who appreciate the value of symbols and are careful and painstaking in their work need have little fear of errors in what they are doing, provided they are able to check their symbolic calculations by graphical methods, when possible. One who has not been educated as a mathematician is not competent to form an opinion as to whether all men can acquire a modern symbolic method of scientific work. I have no reason to believe that it is impossible, but very likely most of those people who are untrained in mathematics experience difficulty in taking up such methods late in life from the fact that they have not had a grounding in the meaning of the terms which seem so unfamiliar to them at the start.

I would caution each one of you, upon leaving school and going into active business, to lose no chance to keep well up in your mathematical studies by an effort, by doing work of any kind in your off hours which will prevent you from growing rusty in what you have learned at school. This is easier if you are following engineering as a profession. Then there is frequent call for you to use this knowledge, and each day you find new opportunities to keep up your practice, but, on the other hand, the amount of work that is required from each one of us in these last years of the nineteenth century, often leaves the mind and body too fatigued after the day's labor to give attention to studies that are not of prime necessity, for the moment, in our lives. The economy of an engineering establishment calls for each one to do his best in his own province; and, if he can delegate to another the purely mathematical part of his work, he is sorely tempted to do so, for the reason that it leaves him the more time to do that work which is really the most profitable for him to prosecute. So it has come now to the condition of employing men in all large establishments especially for he mathematical part of the work. Those who are engaged in

actual experiments hand over their accumulated data to others to formulate and put into shape for their reports for practical use.

The demand, too, for expert testimony, is greater than formerly, and the fact that all engineers are liable at some time to be called into court to testify, should make them careful to learn the value of words, and to acquire habits of quick mental operation, and also to acquire the habit of memorizing and localizing all their knowledge obtained by experience. Those men who are called upon to give testimony before a jury or before a master soon appreciate the difficulty of the position, and, if they lack ready command of language, they stumble, and are covered with confusion, when probably they are fully competent to give the testimony asked of them. To acquire the habit of expressing one's self clearly before others, it is well to carefully weigh one's words, and to not be over-hasty in expressing conclusions without thinking carefully as to the possible use that can be made of the testimony one is giving. Each question that is propounded, particularly in cross-examination, must have a meaning that is leading up to something that is presently to be sprung upon the witness. If one fully understands the case, he has in hand, understands it as if it was part of himself, and then makes no effort to go beyond the exact truth as he understands it, he stands less chance of being wrecked in cross-examination, than he does when he aims to sustain a position which he does not feel in his heart to be a sound one, and yet for politic reasons he may think it his duty to endeavor to maintain. Superficial knowledge is very dangerous at such times. In fact, whatever we have to do is worth doing well from the start, no matter how trivial each separate item of that work may be. Success in life depends upon the faculty of taking pains, and it is this taking pains as to each minute particular of everything that we have to do that makes the total of our work acceptable, and what it should be.

BROADENING OF THE FIELD OF STUDY IS WIDENING OF THE PATH OF LIFE.

Mr. DeCourcy May, when at school in Paris, had an opportunity to be present at a trial of some steam engine or plant, at which time there was a notable gathering of distinguished engineers. Among them was Scott Russel, to whom Mr. May was presented as a young American aiming to become an engineer. He, in the enthusiasm of youth, asked this noted man if he could advise him as to any particular line of study he should take up with the prospect of its being of use to him in his after life. After a moment's thought and consideration, the engineer replied: "Well, young man, I should advise you to study Chinese"; and, seeing the look of astonishment on the youth's face, he then qualified this statement by explaining that no one could foretell what might be of the most use to him. Often, by the merest accident, studies that have apparently no particular bearing upon the line of the profession chosen have proved to be the most useful.

The reason why he named Chinese, I presume, was that by naming the least probable of all subjects for study as being of use to an engineer, he could emphasize this condition of unexpected lines of thought becoming prominent factors in the life of an engineer. My own experience has been full of incidents that would go to sustain this position.

There is a utility, too, in sometimes deviating from the beaten track or line of studies that is laid down as needful for any particular profession, whether it be for law, or medicine, or divinity, or engineering, or anything else. The effect of this widening of the field of study is a widening of the path in life. It has also a very notable effect upon the growth of the mind. I have had an opportunity, quite recently, of watching the changes that have taken place in the work done by professional men as they advance in life. With some, we find that the possibility of doing good work, as an engineer particularly, is limited to something much below the aver-

age threescore years and ten, said to be the ordinary life of mankind. When active mental usefulness is extended beyond the ordinary length of time, it will be found that there is a versatility in the talents of the man. Those who have, with the greatest perseverance, confined their line of thought to one particular subject, and have endeavored to do the best work in one direction, are usually those who later in life find it impossible to pick up any new subject. This is very apparent at the present time, when the kind of education that is rendered possible through the technical schools is being appreciated. Men who have distinguished themselves as engineers, without such technical education, are often unable to keep up with the advance in the arts, owing to their inability late in life to apply themselves diligently and earnestly to new studies and new lines of investigation. You will find that the men who are at the head of large engineering establishments, and who have been for many years prominent as inventors in the particular line of their own pursuit, find it extremely difficult to take hold of and understand the modern science of electrical engineering. There is, perhaps, no branch of engineering practice that is more easily understood and mastered than the arithmetic of electricity; but it comes to the man who is not a mathematician as something that is too difficult for him to take up, and each time that he comes to apply himself to it he meets with discouragement, partly from the lack of clearness in the writers, and partly from the great volume of immaterial matter that hides the little real truth that is needed for a clear understanding of the subject.

If you choose to follow this line of thought, you will find that the mind, to remain active, must be, of course, contained in a healthy body, and advancing years are very apt to bring with them physical troubles that are not conducive to mental exertion; but, even with the disadvantages of physical disability, there may be mental strength, if the balance of forces has been kept somewhat even. No athlete can become one worthy of the name unless he trains every muscle of his body. No mental athlete can be what he should be unless

he, too, with due care to his physical welfare, trains every element of his mental being.

THE VALUE OF EXPERIMENTAL WORK.

The cost incident to experimental research is in many cases so great as to deter manufacturing, light and power companies, and the like, from undertaking such experimentation. Instances can be cited where a company, hoping for a return from such venture, has authorized some one very talented expert to follow up one line of investigation, which has ended in finding that the business profits would not stand the cost incident to the undertaking. Such work can be done at less cost when each subject investigated is well thought out in advance, and the line of experiments mapped out beforehand to meet the wishes of the administrative head of the company.

No one can visit the workshops of the electrical manufacturing companies without being impressed with the number of electrical experts employed in each; so also with the number of draughtsmen employed, and the extent of the clerical or office force, all representing an expenditure in wages alone, that, if not kept within bounds, may readily consume all profits, as has often been the case. These seemingly unremunerative employees, however, may, under proper management, prove more profitable than the skilled labor engaged in the workshops.

The technical corps is mostly recruited from such schools as the Stevens Institute of Technology and other technical schools. A well equipped student may find himself rich in experience after a [illegible] such an establishment, or he may find means to make his [illegible] experience profitable by more direct methods.

Mr. Nicola Tesla, with his intense enthusiasm and his wonderfully well trained, pursues scientific investigation as a pleasure, and the world at large cannot fail to be the gainer from his work. It is essential that such men should find friends to help them, and

Government aid in such case would be wise, but unfortunately the value of any man's work cannot be estimated at the beginning, and results of great worth must be obtained before his fitness as an original investigator can be appreciated. Dr. Tyndall's unaided labors made him worthy of the position in the Royal Institute once filled by Farraday, by Thomas Young, and those who preceded him. Lord Kelvin, as President of the Royal Society, had achieved his distinction and profited, as Sir William Thomson, by his inventions made by Professor Thomson.

Young Mr. Hall, whose process of extracting aluminum from the ores is likely to make that valuable metal abundant and cheap, its cost being measured by the cost of power, was not remarkable as a brilliant student at school, nor could his present value have been estimated with any exactness by his teachers, who knew him only as a rather improving scholar, as they measure men, while he was all the while laboring in one direction to find the means to accomplish what he had deemed possible.

In my own case, when I left school as a boy, I knew little of Latin, after several years work with books I did not understand, was slow with figures, from having been unable to see any use in the dry studies that had no bearing on anything I expected to do. I looked forward to vacation, not on account of pleasure trips to sea-side resorts, which I never saw, but for a chance to work in my father's shops. I was low in some classes, because I spent my spare time in reading scientific books that formed no part of the school course. I took no drawing lessons, because they were an extra which I could not afford, and because, in my boyish conceit, I could see no good in the teacher's methods as exhibited in his pupil's work. My pencil has always been my constant and common tool for expressing thoughts, and is now, and I had no desire to copy pictures. At sixteen a boy's judgment is not worth much as to what he shall or can do. Well, in my case, after working on a farm for a few years, mastering the use of a farmer's tools, as well as increasing my skill as a carpenter, as a maker of harness, and of the tools

a harness-maker required, doing such odd jobs as came to me, when nineteen years old I accepted a position as draughtsman in a rolling mill in Cincinnati, O., and in two years I had been made Superintendent of the establishment. My experience in the world does not argue against time spent in good schools. Had technical schools such as this been in existence, I would have been glad to have taken advantage of such an opportunity to get what I longed for, and labored for, and have unceasingly sought for, with earnest intensity all through the years of my life. Even now, but for the need of using my experience for the benefit of others and for my own support, I am not ashamed to say that I would gladly, so far does my thirst for knowledge prompt me, take my place as a Freshman in a school honoring me with a place among its teachers. In such event I would not want any partial, any special course. Daily and hourly I feel the need of what you are getting from books and from your many able exponents of those books, in fact, the makers of many of the best books you use. How have I done without such instruction? I have not been ashamed to say I do not know, and to seek help from those who do know, and by this means have spread my school days to great disadvantage, and yet to good purpose, over 60 years to gain (apart from experience and the knowledge of facts) what you have the means of mastering as to methods in four years, which methods, if you diligently use them afterwards, in season and out of season, will be found both useful and profitable.

If a chance is offered to any one of you to make your knowledge of use to others in experimental work, I would urge you to study economy in your methods, and to direct all your attention to results that will be of use, and to avoid all following of blind paths in scientific jungles in hopes that some one may lead to a good, naturally developed clearing, that can be worked without any trouble of cutting away the brush and timber and pulling up stumps to get at the tillable soil below.

BALL BEARINGS.

The introduction of ball bearings, which first found practical use in diminishing the friction of bicycles, has developed a trade of manufacturing such balls, and the cheapness with which they can now be produced would tend to still further increase their application in machine construction generally.

One of the most notable examples of the use of balls is to diminish the friction of the collar that sustains the hook of a large crane. Without these balls the difference between the friction of rest and the friction of motion is so great that men are often seriously hurt by endeavoring to turn a load suspended upon the crane hook which requires a great deal of exertion to start it, and when it does move, goes further than is intended, often leading to serious accidents. By making the crane hooks with flat washers, between which numerous small balls are placed, resting on hardened surfaces, there seems to be no difference between the friction of rest and the friction of motion, and hooks heavily loaded are turned with remarkable ease, so that the use of balls, distributed over plane surfaces, is quite common, there being no basket or grooves to separate the balls, but they are allowed to move at their own will in whatever direction they are inclined to go.

Some recent experiments in the application of balls to the shafts of dynamos has shown that the friction can be very much diminished, and a yet slight end motion of the armature shaft necessary to keep the brushes in good order upon the commutator is admissible, which would not be the case if rollers were used for the same purpose.

There is very little literature on the subject, and the theory of ball bearings has not been worked out and published. It may be interesting for you to know that some experiments have been going on for some time past in reference to the size of the balls best suited to the different purposes. In the case of hooks for cranes carrying about 50 tons, between 250 and 300 balls, each of three-eighths inch diameter, are scattered between the flat plates, with the

idea that the more points of contact the longer the balls will last, but some experiments are now being tried with balls of different sizes, and motion kept up under loads to determine their durability, with a leaning in favor of larger balls and fewer of them.

If any of you choose to take up this matter and study it, you must bear in mind that the balls themselves do not rest upon a mathematical point when impinging upon a flat surface; at least we can infer that they do not from the fact that if a hardened steel ball be dropped from a considerable height upon a hardened steel plate it will recoil very nearly to the height from which it had fallen, so nearly to the same height as to lead one to consider the steel of both plate and ball as being highly elastic. This elasticity implies distortion of form, and no matter how fine a film of moisture there may be upon the plate, there seems to be an appreciable surface of contact indicated by the disturbance of the film on the surface.

A great deal might be learned by careful experiments and much good result from the facts illustrated by experiments, not only in regard to the size of the balls but also the methods of restraining them.

It has been found, in axle work under street cars, that a small wire cage is sufficient to hold the balls in place, and, after many months' wear, the cage shows no sign of wear from rubbing. Where balls are used for end thrust of a rapidly rotating shaft, it has been customary to confine the action to a single line of balls, inasmuch as it is not advisable to put in a single cage balls of the same diameter running at different distances from the center of motion, as they cannot all move forward at the same rate, and one or the other must rub upon the cage and produce a retarding friction as well as a wear upon the metal.

ARTIFICIAL MOLDING SAND.

The art of iron founding, as pertaining to the machine shop, has probably had less attention paid to it as a scientific process

than almost any other part of an engineering establishment. A good foreman of the foundry has heretofore been considered one who is familiar with all the tricks and methods of molding, as well as informed as to the charging of the cupola to get the irons that would be suited to each particular kind of work. When the foundry is organized for one particular kind of work, like hollow ware or stove making, the iron that is selected for the purpose is usually well understood, and there is little skill in melting or pouring, as compared with that required by the various products that must be brought out from the cupola for machine castings and the better quality of fine work.

Not only one lecture but several volumes might be written upon the foundry, without exhausting a subject that is full of interest, and particularly interesting to young men going into business, as generally the equipment for a foundry requires so little capital as to permit men of moderate means beginning a business on a small scale, and gradually increasing the capacity of their place as they become able to extend their facilities. Of course, in such beginnings the flasks used are made of wood, and the cupola even may be improvised from the shell of a cast-off cylindrical boiler, but it is not of such methods that I wish to speak to you to-day, but of some matters that deserve your most careful consideration.

Within a decade, the number of educated men who have gone into the foundry to experiment and improve methods has increased continually, and so also has their skill and efficiency increased. They have a good field to work in, and find that scientific methods have been discouraged by the men in charge, who have no idea that the character of the iron may be changed by mixture and by chemical treatment, and are not aware from what causes the different kinds of metal are hard or soft, nor do they know what makes one metal better than another for a particular kind of work. I would call your attention, to-day, for the first time in any of my lectures on this subject, to the fact that the molding sand itself is

part of the necessities of the foundry which need a great deal of thought, and may be very much improved. There are qualities of sand dug in various places that go by the name of molding sand. They are sands that have a base of silex, and with it some other material that is usually known as loam or clay that, mixed naturally in proper proportions with the sand, gives the adhesive qualities required and yet makes the mixture open enough to allow the escape of gases into the fine holes that permeate the mass. It is only of comparatively recent years that the idea has occurred to anyone that spent molding sand has any other value than for building purposes; and, in this particular, those who know the value of spent sand for making mortar are anxious to secure it from the foundries, because the silex has not been injured by the heat, and most of the clay and organic matter has been destroyed or burned out. In all large machine shops the buildings required are invariably done with molding sand, and it lends itself particularly well to the colored mortars which are fashionable at the present time. I would have you, when you have an opportunity, think seriously of the capabilities of restoring molding sand by chemical analysis for composition, and use the microscope or experimental tests to determine methods. It seems but reasonable that if a good quality of molding sand consists of silex with a certain clay that binds the particles of sand together, it is the business of the expert in this line to determine the relative character of the particles of silex that are best adapted for the purpose, and then to find out for himself what is the binding material that makes it available for his use. This being the case, what can be more simple than the restoration of the molding sand by the addition of clays in proper proportion, or even the addition of other mineral substances that may greatly improve the quality of the material. That people are thinking of this method of treating is shown in trade by the fact that less molding sand is available for building purposes than formerly, and also that the dealers in molding sand find their largest customers using rather less of what they dig for the purpose. It is through the dealers

that the methods of the managers of one foundry get to the knowledge of the managers of others, as it is quite a common thing for dealers in seeking trade to think that they are serving the would-be customer by informing him of what some other person may be doing in the same line, at least so far as they know.

Another incentive that has been given to the proper preparation of molding sand, either by the mixture of different qualities or by their artificial production, comes from the extended use of machines for molding, and this subject should not be neglected in your search for knowledge to improve methods and material.

There has been of late years a very decided improvement made in foundry methods, growing out of the introduction of students from the technical schools as metallurgists into our large foundries. The knowledge of the cause of chilling property of cast iron is a rather recent acquisition. In the first place, those who discovered that the hot blast irons with poor chilling qualities could be used in chilled wheel making by the melting of Bessemer scrap in the cupola with the iron, arrived at this knowledge through experiment, and probably without any fixed idea as to the cause of the chilling property. When men began to think on this subject, and to consider that from the same furnace a great many different qualities of pig iron are produced, some white and brittle, some gray and soft and strong, then the idea began to assume shape that there might be changes made in the nature of the pig, either by mixing metals of different quality or adding something that might change the character of the metal after it had run into the ladles; thus, if the minute black specks that are seen in many castings after they are planed are due to free carbon in the form of graphite, nothing is more natural than to add something to the metal that would take up this carbon and no longer allow it to exist in these fine particles, such as the addition of manganese or other minerals or metals known to makers of steel.

With increased experimentation and the introduction of scientific methods into the founding, it has been proved that metals

seemingly unfit for machine castings may be rendered soft and easily tooled, and, at the same time, have their strength very much increased, by such treatment as will enable the metal to be poured against chilling surfaces without any chilling effect, so as to permit, in the first place, the use of iron cores, and in the next place to permit the placing of chilled surfaces to take off the heat just where the mass of metal wants to be cooled the most rapidly to prevent shrink holes from occurring. Those of you who have paid any attention to the casting process must have noticed the difficulty of having uniform cooling and uniform shrinkage taking place when small arms are attached to a heavy rim; for instance, in pulley and flywheel work. There has to be considerable ingenuity in the method of feeding the mold to make up for the shrinkage, and to supply vacancies that would occur if the metal cannot be kept fluid during the shrinking process and gradually supplied through the sinking heads. If now the larger parts be cooled by masses of iron, while the smaller parts, protected by a non-conductor, cool naturally, a mold may be made that would be scientifically correct as to uniformity of cooling in all parts. The only difficulty in the way of this proceeding arises from the fact that any sudden cooling of cast iron produces the effect known as chill, and crystals are set up and hardness is the result.

It is not possible for me to tell you exactly how far this improvement has been carried, or to tell you with any exactness of the methods that have been resorted to by the more advanced foundrymen, but I would be remiss in my duty if I did not call your attention to the fact that there is room for your work, and plenty of room too, to render yourselves valuable to your employers if your attention is turned towards this important part of the engineer's profession. I would caution you, however, against relying upon book knowledge in this regard, as, so far as I have been able to judge, the literature on the subject is not up to the state of the art, and most of the books have theories that may or may not be correct.

As bearing upon the best method of acquiring knowledge, I was rather forcibly struck the other day by a method adopted in a large electrical establishment where some of the experts, in instructing those who had been employed in a manner equivalent to serving an apprenticeship to the business, gave underlying principles of electrical engineering and the arithmetic of electricity, suggesting to the pupils means of familiarizing themselves with the various phenomena by experiments, and cautioned these working students against reading any books upon the subject on any condition, for the reason that by reading in the early part of their education they could not help imbibing some of the theories of the writers, and those who are teaching them wish them to train their minds to avoid all theoretical knowledge and to stick, as it were, to the practical knowledge which can be obtained in the manufacturing establishments where, as is always the case, the experimental facilities are far greater than in the laboratory of those who are studying only, and not carrying out this work in mercantile form.

CLASSIFICATION OF STEEL.

In former lectures I have urged upon the class the necessity of the physical tests for steel, and have shown the disadvantage of limiting the steel maker by arbitrary chemical requirements in the specification, and, as an illustration of the method of classifying steel, I have given the grades as classified by the Midvale Steel Company. Having made recent inquiry into the classification in regard to any changes, the following has been procured as the latest statement on the subject:

CLASSIFICATION OF STEEL MADE BY THE MIDVALE STEEL COMPANY.

Class o. Carbon .1 to .2 per cent.
Approximate tensile strength from 55,000 to 65,000 pounds.

Class I. Carbon .2 to .3 per cent.
Approximate tensile strength from 65,000 to 75,000 pounds.

Class II. Carbon .3 to .4 per cent.
Approximate tensile strength from 75,000 to 85,000 pounds.

Class III. Carbon .4 to .5 per cent.
Approximate tensile strength from 85,000 to 95,000 pounds.

Class IV. Carbon .5 to .6 per cent.
Approximate tensile strength from 95,000 to 105,000 pounds.

Class V. Carbon .6 to .7 per cent.
Approximate tensile strength from 105,000 to 120,000 pounds.

Class VI. Carbon .7 to .8 per cent.
Approximate tensile strength from 120,000 to 135,000 pounds.

Class VII. Carbon .8 to .9 per cent.
On heats of this carbon and above, tensile strength is not considered, as they are generally used for spring steel and tool steel, in which the fitness of the material for the purpose wanted cannot be decided by the tensile strength in a test bar.

Class VIII. Carbon .9 to 1 per cent.

Class IX. Carbon 1.00 to 1.10 per cent.

Class X. Carbon 1.10 to 1.20 per cent.

It is of course understood that while this classification holds good in a general way, the other chemical ingredients besides carbon, as well as treatment, may so affect the tensile strength that, while the percentage of carbon would place it in one class, other chemical ingredients or physical treatment may bring it (as far as tensile strength goes) into one of the other classes. As a general thing, it has been found that a high percentage of manganese, say above .7 per cent., up to and including 1 per cent., will exert a much greater hardening influence on steels of high carbon than of steel below .5 per cent. in carbon; while the other chemical ingredients seem to exert a uniform hardening influence on all grades of steel.

The purposes for which the different classes of steel are recommended by the Midvale Steel Company, taking into consideration the many different specifications for the same purposes that are received, are as follows:

Class o is generally used where welding quality is desirable and it is recommended for nothing else; although several of the railroad companies and locomotive builders use it for axles and crank pins, mostly, it is thought, for the reason that they are not used to working the harder steel on their machine tools, and their men complain that they cannot make wages at the rate they are paid. Complaint is then made that the steel is too hard for the

purpose intended, and the ease with which it can be machined is apparently the only consideration.

Classes I. and II. are used for propeller shafting, axles, and general machinery work. Also used for rifle-barrel steel, steel castings where toughness is the principal requirement, and finally, in the higher grades, where it approaches Class III., for gun tubes.

Class III. is principally used for Pennsylvania Railroad axles and crank pins, and for parts of machinery where a high elastic limit is required. This class is recommended for axles and crank pins, and, where the choice is left with the makers, they invariably use it for this purpose. It is the class which, in their opinion, is best suited for steel forgings of all description, with the condition, however, that the forgings should be thoroughly annealed. If this is not done, the lower class is preferable, as the strains left in the forging are not apt to be injurious in the lower carbon steel. This class is also used for gun forgings, jackets and hoops, the high requirements as to elastic limit making it necessary to have a good percentage of carbon.

Class IV. is used also principally for gun forgings and for large locomotive tires.

Class V. is used principally for tires for freight service and car wheels, and for forgings for air vessels for torpedoes, and also for steel castings where great wear is desirable, such as hammer dies, roll pinions, etc.

Class VI. is used mostly for surgical instruments and grinding machinery.

Class VII. is used for spring steel.

Classes VIII., IX., and X are used for various grades of spring and tool steel, the highest grades being used for cutting tools and the lower grades for chisels, reamers, etc., etc.

It is necessary to remember in this classification, that while the carbon and tensile strength govern the classes, the chemical composition of the different heats that come under one class varies considerably. In the case of ordinary machinery steel and tires, the

makers endeavor to keep the phosphorous limit below .06 per cent. This is the case also with their steel castings. In gun forgings, on the other hand, their phosphorous limit is below .03 per cent., as well as in tool steel and spring steel.

At the present moment, the greatest interest is taken in the magnetic qualities of steel, as compared with the best Norway iron; and from recent experiments it will be seen that conclusions cannot be drawn with safety from a few experiments, particularly in regard to the alloys of various metals with steel. The statement has been broadly made that a large percentage of nickel introduced into steel castings destroyed the magnetic qualities of the steel to such an extent as to make this alloy particularly desirable or useful for the bolts that clamp the punchings of the armature in the dynamo together, the general idea being that these foreign substances were all acting injuriously. Some recent experiments have been made by the Bethlehem Iron Company bearing upon the dynamos that are to be made for Niagara, which seem to show that when a small quantity of nickel only is used, the magnetic qualities are improved to such a degree as to make its employment advisable, making nickel steel, properly prepared, higher in its capability of magnetization than even the best Norway iron. This statement does not hold good in all degrees of excitation, but is said to be particularly good at the amount of excitation to which field magnets are usually subjected.

Mr. L. B. Stillwell, in his examination of this metal, concludes a report on the subject with the words: "I am emphatically of the opinion that no better material can be secured." The effect of the mixture of foreign substances with steel is one that is worthy of the most careful attention of the students of technical colleges, and would form an admirable subject for a thesis, as the experiments to be reliable need not involve great cost, and would give opportunity for a considerable display of ingenuity in devising methods of making the tests, and the manner of showing the results by graphical methods.

A SIMPLE WATER RESISTANCE PRONY BRAKE.

BY F. M. LEAVITT, '75.

IN constructing a series of Whitehead submarine torpedoes it was considered desirable to test the propelling engines so as to determine their useful horse-power before they were fixed in the main body of the torpedo.

The engines, as used in the torpedoes, drive screw propellers, so that to absorb the power by a brake, and secure the conditions of service, the brake resistance had to be applied without causing any lateral strain upon the propeller shaft. To accomplish this by any form of band brake was impracticable, in view of the multiplication of weighing devices involved.

Furthermore, the development of power by the engines was confined to 30 seconds, or less, which was the interval of time required to exhaust a reservoir of compressed air supplying the power; and the time to adjust and weigh the resistance of any brake depending upon the friction of solid bodies, would probably reduce the period of measurement too much to secure reliable results.

To avoid these difficulties a brake was adopted at the suggestion of Professors Webb and Denton, in which the resistance was afforded by the friction between disks of metal and a mass of water. It was arranged as follows:

Four steel disks 24 inches in diameter, about one-eighth inch thick and one-fourth inch apart, are fixed to a vertical shaft. The disks revolve in a cast-iron curb, to which are attached three steel disks of the same thickness, so that the space for water between the disks is about one-sixteenth of an inch, which is also the clearance space between the outer disks and the curb. The hubs at the center are 5 inches in diameter, so that the total surface of revolving disks

is composed of eight circles 2 feet in diameter, less the 5-inch hubs. The cast-iron curb is free to rotate on the shaft. To measure the resistance a lever is fixed to the floor by a pivot at A, Fig. 1, and connected to the curb by two parallel links B and C At D is placed a spring balance. The object of the links is to remove the side strain from the shaft bearings, and transfer it to the small pivot at A. The lever arm A D is 4 feet in length, so that 25 × tension on scale = foot-pounds per revolution.

The engines to be tested were coupled direct to the vertical shaft of the dynamometer, and in all tests the curb was kept entirely filled with water, so that for each speed of revolution of the engine the resistance was constant.

The engines, some fifty of which were tested, are of the Brotherhood type, having three single-acting cylinders, 3⅛-inch bore by 2¾-inch stroke. The initial pressure of air used in different tests ran from 400 to 800 pounds per square inch.

Compressed air for driving the engine was stored in a reservoir, so that the loss of pressure on the gauge compared with the horse-power of the engine gave the relative economy of air consumption. The duration of each test was from ten to thirty seconds.

In the first twenty-seven tests the following data were observed, the results of which are given in the table below:

1. Duration of run.
2. Revolutions of engine.
3. Initial and final pressure in air reservoir.
4. Initial pressure on engine, which was practically constant throughout each test.
5. Tension on spring balance.

From this data the horse-power developed by the engine, and foot-pounds of work done per pound of air, were calculated, as shown in columns 9 and 13.

The resistance of the brake depends upon the speed of revolution. The horse-power developed is therefore a function of the

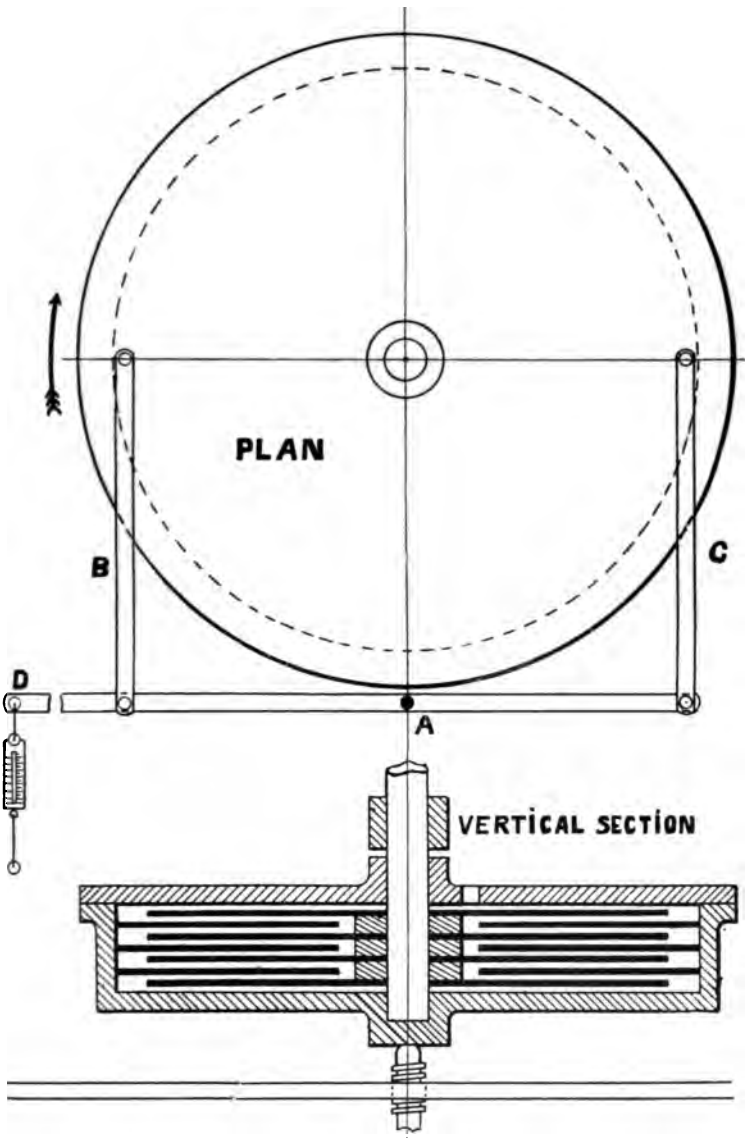


FIG. 1.

tension on the scale balance; and, assuming that resistance varied as the square of the speed, a formula was constructed as below. The constants were obtained by plotting the results of the runs already made and drawing the mean curve as shown in Fig. 2. In column

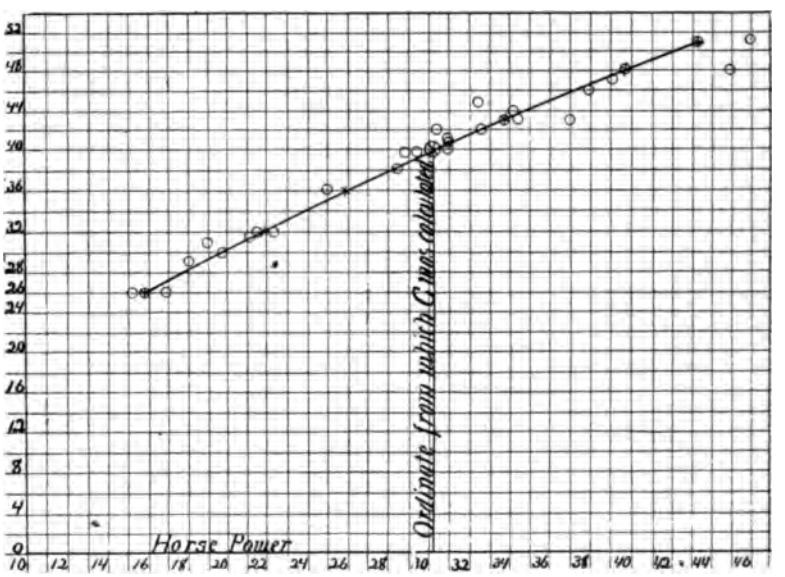


FIG. 2.

12 is given the horse-power as calculated from the formula. The discrepancy between the observed and the calculated horse-power may easily be accounted for by error in timing the duration of run with a stop-watch.

It follows therefore that this arrangement of brake permits the horse-power to be determined by simply securing the average reading of the spring balance, without regard to the speed. The instrument is therefore especially adapted to power measurements during very short intervals. The fact that the resistance afforded by the disks is practically equal to the friction of water flowing over them with a velocity equal to their speed of rotation enables their area to be easily determined for any given range of horse-power.

Formula for horse-power:

$$\text{Horse-power} = \frac{T\sqrt{25{,}000\ T}}{1{,}320}$$

T = tension on scale balance.

This formula is obtained from $T = C R^2 \therefore R = \sqrt{\frac{T}{C}}$

R being the velocity of revolution and C = constant.

$$\text{Horse-power} = \frac{T \times 25 \times R}{33{,}000} = \frac{T \times 25 \times \sqrt{\frac{T}{C}}}{33{,}000} = \frac{T\sqrt{\frac{T}{C}}}{1{,}320}$$

Number of Test.	Shop Number of Engine.	Data Observed.					Revolutions per Minute.	Horse-Power.	Calculated from Formula.			
		Amount of Air Used.	Initial Pressure on Engine.	Tension on Spring Balance.	Duration of Run, Seconds.	Total Revolutions of Engine.			Duration of Run.	Revolutions per Minute.	Horse-Power.	Pounds Air per Horse-Power per Hour.
		Lbs.		Lbs.								
1	100	11.75	450	32	17	250	880	21.5	16.8	891	21.7	111.
2	"	18.25	500	36	22½	340	906	25.0	21.5	948	25.9	118.
3	"	11.75	525	39½	18	290	960	28.8	17.5	993	29.25	82.6
4	"	11.75	550	39½	19	310	980	29 5	18.7	993	29.25	77.3
5	"	8.25	550	40	12	205	1,020	31.0	12.3	1.000	30.3	80.8
6	"	10.9	550	39	16½	270	980	30.0	16.4	987	29.2	82.1
7	"	7.3	600	38	12	195	975	28.5	12.0	974	28.1	77.8
8	"	13.6	425	31	30	420	840	19.0	28.7	877	28.6	82.5
9	"	4.4	425	29	9½	144	960	18.0	10.2	847	18.7	83.0
10	"	5.5	425	30	13½	195	864	19.7	13.5	862	19.6	74.7
11	"	10.9	625	41	19	315	995	31.0	18.7	1,012	31.5	66.4
12	"	11.9	675	43	16	280	1,050	34.5	16 2	1.036	33.8	78.2
13	25	10.9	500	31½	23	340	887	21.2	23.0	885	20.6	82.5
14	54	6.3	525	26	13¼	190	854	16.9	14.0	802	15.8	102.0
15	"	10.1	525	26	24	315	786	15.4	23.5	802	15.8	97.8
16	"	12 0	725	32	21½	335	924	22.4	22.4	891	21.7	88.5
17	"	12.6	750	44	19	325	1,026	34.2	19.1	1,048	34.9	67.5
18	59	13.8	750	47	18½	340	1,100	39.1	18.8	1,043	38.6	68.2
19	41	11.75	750	42	20	320	960	30.5	18.7	1,024	32.6	70.0
20	"	10.0	750	42	16	270	1,032	32.75	15.8	1,024	32.6	70.0
21	36	12.6	750	43	19	315	1,000	32.5	18.2	1,036	33.8	72.5
22	47	12.6	725	46	17½	320	1,090	38.0	17.9	1,072	37.3	68.0
23	6	13.8	775	51	18½	330	1,200	46.0	17.5	1,129	43.5	65.5
24	52	11.8	725	41	19½	325	1,000	31.0	19.2	1,012	31.5	70.0
25	11	10.0	725	41	19	315	1,000	31.0	18.7	1.012	31.5	61.0
26	37	10.0	725	41	17½	290	1,000	31.0	17.2	1,012	31.5	66.5
27	6	11 8	750	43	17½	320	1,140	37.0	18.5	1,036	33.8	67.5
28	—	1.81	190	14	13	125	577	6.1	12.5	590	6.27	83.
1	2	3	4	5	6	7	8	9	10	11	12	13

THE DETERMINATION OF THE CALORIFIC POWER OF COALS BY MEANS OF A MAHLER CALORIMETER.

Abstract of Graduation Thesis of

ANSON G. WILBUR, '93. BEATTIE A INGLIS, '93.
JOHN F. PAULSEN, '93. ORTON G. DALE, '93.

BY PROF. A. R. LEEDS.

THE chief difficulty with calorimetric determinations has been lack of a good calorimeter. Many instruments have been devised, all more or less complicated, but until recently there was no really reliable instrument for this purpose.

Lavoisier and Laplace were the first to make experiments on the determination of the heat of combustion by means of a calorimeter. Their calorimeter consisted of an earthenware vessel surrounded by ice. They made experiments with charcoal and hydrogen, and found that 1 part of charcoal melted 96.5 parts of ice, and 1 part of hydrogen 295.6, or reduced to calories, 7,720 and 23,648 respectively.

Hassenfratz, Clements, and Desonnes also made experiments with ice calorimeters. Rumford, in 1813, made the first comparison of charcoal and wood. According to him 1 part of charcoal heated 52 to 54 parts of water from the melting point of ice to boiling, and 1 part of wood 25 to 40 parts. Graffe burned sugar-charcoal in a water calorimeter with oxygen, and found for it 7,682 to 7,801 calories.

These experiments, however, were all very crude and unreliable. Dulong was the first to make a more exact and extended series of determinations. Although Dulong's results were the best

that had been obtained at his time, it is now known that they were far from being exact. He used a simple form of water calorimeter.

Ure burned the substance whose calorific power was to be determined in a small combustion chamber with atmospheric air, and let the gases of combustion rise through pipes passing through a keg filled with 300 to 400 kilogrammes of water.

Bargum employed a similar piece of apparatus to determine the calorific power of turf; only he placed the combustion chamber in the water.

Deville used a small tubular boiler.

About the same time Bolley invented a much more perfect instrument than his predecessors, but too complicated to be useful.

Andrews also brought out a calorimeter consisting of a closed copper shell, which was completely immersed in water, and in which the substance was burned in an atmosphere of oxygen.

The most complete determinations of calorific power were carried out by Favre and Silberman, in 1852, and many of their results are still accepted as standards. Their apparatus and experiments are so well known that it is needless to dwell further on them.

Thomsen, in determining the calorific power of hydrogen, made use of a calorimeter consisting of a platinum ball of about 500 cubic centimeters capacity. It was wholly immersed in water. The hydrogen was led in through one pipe and the oxygen through another.

Schuller and Wartha used an ice calorimeter to determine the calorific power of hydrogen.

The process recommended by Stohmann and used by Frankland in his investigations on the specific heat of human foods is quite different from any of the preceding processes of burning the matter to be investigated with free oxygen. His improvement consisted in taking for a water vessel a cylinder of polished tin plate surrounded to the height of the water level with six folds of flannel and last with a covering of tin and a rubber band. The substance

to be burned is mixed with potassium chlorate, manganese trioxide, and powdered pumice stone. This instrument is quite difficult to operate, and there are so many corrections to be made, that the results can be only approximate, even when the apparatus is used by an expert.

Gottlieb, Schwackhofer, and Fischer have, in their investigations on this subject, used instruments of their own design, but do not seem to have succeeded in producing a simple practical calorimeter. Fischer has come nearer producing a good instrument than any of the above-mentioned investigators; but experiments with one of his instruments, now in the Institute, have shown it to require very careful handling to obtain reliable results; and, under the most favorable circumstances, only one or two combustions can be made in a day.

The experiments carried on at the Munich Experiment Station by Sheurer Kestner have attracted a good deal of attention, and have by many been given a value they do not possess. These experiments were boiler tests, made with a boiler especially constructed for the purpose. In these tests so many sources of loss were overlooked as to make them of no practical value. (For an account of these tests, see Bericht der Heizversuchstation, by H. Bunte.) According to the published report of the tests many of the losses were only guessed at. These trials proved conclusively that a boiler is not fit to determine calorific power, but that carefully conducted trials are very useful in showing the way heat is used up in a boiler. Exact determinations of calorific power can only be made in a laboratory.

The instrument which is used most extensively at the present day for determining the relative value of fuels is Thompson's calorimeter. Although it gives determinations which are sufficiently accurate for commercial purposes, it is an inconvenient instrument to use, and allows all the gases of combustion to escape into the room.

As shown by this hasty review, no really good, simple calorimeter had been produced up to the year 1891. In this year the French Société d'Encouragement pour l'Industrie Nationale placed a sum of money at the disposal of its Chemical Arts Committee to be used in an investigation of the calorific power of the principal fuels used in the industries. The carrying out of this investigation was intrusted to M. P. Mahler, Ingenieur Civil des Mines. He carried out a very extended series of experiments at the laboratory of the Paris School of Mines. The apparatus he employed consisted of a modified form of Berthelot's bomb. Berthelot's instrument, which was originally made for the combustion of gases under pressure, is shown in the accompanying sketch. It consists of a steel cylinder lined with platinum. The sample to be burned is placed in a platinum basket, and after the cylinder cover has been securely screwed down and some oxygen under pressure admitted, the sample is ignited by means of electric connections.

The following description of Mahler's modification of this instrument is abridged from the original paper published in the *Bulletin* del a Soc. pour d'Encouragement l'Industrie Nat., 91 (1892), pp. 317–374. The accompanying sketches represent a vertical section of the calorimeter itself, showing all the attachments, and also a vertical section of the shell to a larger scale. The shell is forged out of mild steel having a tensile strength of 31 tons to the square inch, and an elongation of 22 per cent. It is about 8 millimeters thick, and our instrument weighed about 3,500 grammes, with a capacity of 814.6 cubic centimeters. The capacity of the instrument was made much greater than that of M. Berthelot for two reasons: First, to insure complete combustion, and second, because many gaseous fuels used for industrial purposes contain nitrogen and carbonic acid it is necessary to take a large quantity of them in order to obtain a measurable rise in temperature. The shell is coated on the inside with porcelain to protect it from corrosion or oxidation. This coat of porcelain replaces the platinum lining of Berthelot, reducing the

cost several thousand francs. The porcelain being very thin does not interfere with the transmission of heat. The cover is fitted with a ferro-nickel cock R, with a conical screw and stuffing box E, for the introduction of oxygen under pressure. The cover is screwed down upon a ring of lead P, placed in a circular groove cut in the rim of the shell, making a tight joint. Through the cover passes an insulated electrode, to which a platinum rod is

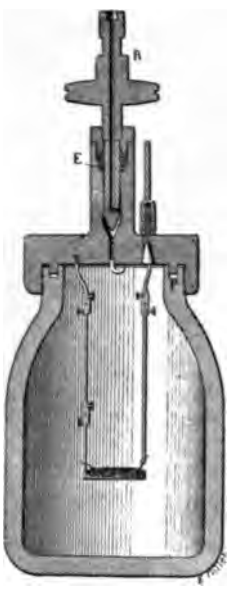


FIG. 1.

fastened by means of a clamp. Another platinum rod is fastened to the cover, and the pan which contains the substance to be burned is attached to this by means of another platinum rod and two clamps. Attached to the platinum rods and passing through the substance to be burned is a small helix of fine iron wire. Ignition is produced by heating this wire white-hot by means of a battery. The calorimeter, the outer vessel, and the various details of M. Mahler's apparatus differ from the analagous parts of M. Berthelot's instrument, the object being to reduce the cost as much as possible.

The calorimeter is of thin brass and in our experiments about 2.3 kilos of water was used. This large amount of water practically eliminates all error due to evaporation. The agitator S is worked by the lever L, which pushes down the rod K, to which the agitator

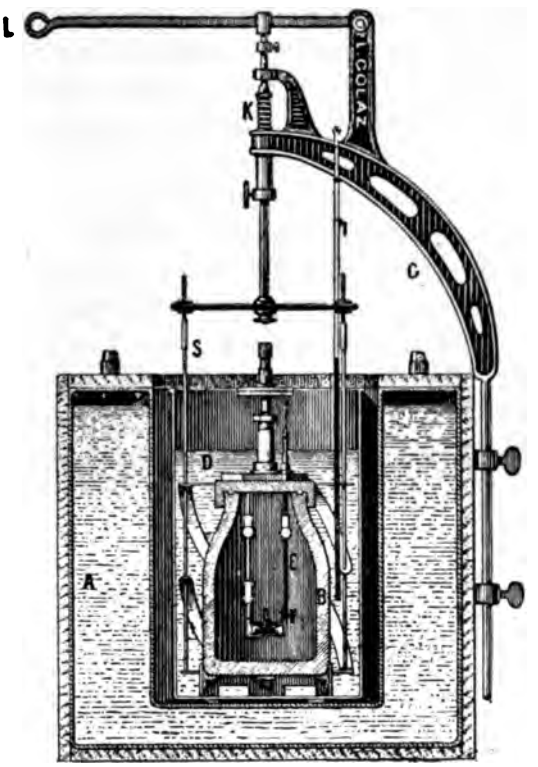


FIG. 2.

is attached. This rod has a spiral thread on it and moves through a nut, so that in pressing it down it also receives a revolving motion, thus very thoroughly stirring the water. The thermometer T should read to the one hundredth of a degree. The thermometer used in our experiments was compared with an annealed standard thermometer, made by Baudin for Professor Mayer in 1891, and graduated by comparison with an air thermometer. The result of the comparison

showed that our thermometer required a + correction of .1 of a degree. The correction was constant for all temperatures within the range of the thermometer. For igniting the substance a battery capable of giving a current of two amperes with an E. M. F. of 10 volts is required. The oxygen was obtained from an oxygen manufacturing company. It was supplied in cylinders of 125 cubic feet capacity at a pressure of 150 atmospheres per square inch. Such a cylinder will supply oxygen enough for about 140 determinations.

Before this instrument can be used for determining calorific powers it is necessary to find the water equivalent of the shell and its appendages. This must be determined with the utmost care, as upon it depends the correctness of all the results afterward obtained. It may be calculated directly from the weights and known specific heats of the parts. It may also be obtained experimentally. In the case of our instrument both methods were employed; but the method by calculation could only be approximate, because the weight of the porcelain of the shell was not known and could only be estimated. By this method we obtained the following result:

Material.	Weight Of.	Specific Heat Of.	Water Equivalent Of.
Brass of calorimeter.....	703.07	.094	66.088
Steel of calorimeter... ...	3,323.24	.1165	387.157
Porcelain	134 078	.179	24.
Platinum	21.3	.0324	.68
Lead.....	9.	.0314	.282
Glass of thermometer.....	12.69	.17968	3.114
Mercury of thermometer..	25.03	.03332	.833
Oxygen	29 1205	.155	3.513
			485.657

In determining the water equivalent experimentally the following method was employed. The shell was charged with oxygen at 25 atmospheres pressure. A known weight of water, about 2,000 grammes, was then placed in the calorimeter, the shell immersed in it, and the whole apparatus placed under the same conditions that

would exist during an actual combustion. The water was then agitated until the temperature became constant, when about 300 grammes of water at a much lower temperature was added, and the whole agitated until the temperature again became constant. Readings of the thermometer were taken every half-minute. From the observed fall of temperature the water equivalent may be calculated by means of the following formula:

Let X = water equivalent of calorimeter shell and appendages.

t = final temperature of water in calorimeter.

t_1 = initial temperature of water in calorimeter.

t_2 = initial temperature of cold water added.

W = weight of water in calorimeter at beginning of experiment.

w = weight of cold water added.

Then we have

$$(t_1 - t)\ W + (t_1 - t)\ X = (t - t_2)\ w,$$

or

$$X = \frac{(t - t_2)\ w - (t_1 - t)\ W}{t_1 - t}$$

The results of 25 determinations gave a mean of 489.97. The highest of these observations being 516.8 and the lowest 459.7. In the calculations 490. is used. We chose this number rather than the one found by the other method because of the uncertainty in regard to the weight of the porcelain lining.

METHOD OF MAKING A DETERMINATION WITH COAL.

About 10 grammes of coal to be tested is finely powdered and passed through a sieve having 10,000 meshes to the square inch. It is necessary that the coal be very fine or it will not burn completely. The powdered sample is placed in a glass weighing tube. The platinum wires and pan are attached to the cover of the shell and the iron wire helix placed in position. A sample of coal is now poured into the pan from the weighing tube, care being taken to see that none is spilled and that the iron wire helix passes through the coal. The cover is then placed on the shell and screwed down

firmly. The shell is now connected with the oxygen cylinder, and the oxygen allowed to flow in until the gauge shows a pressure of about 25 atmospheres. The stop-cock is then closed and the shell placed in the calorimeter, which has been previously partially filled with about 2,400 grammes of water. The thermometer and agitator are adjusted, and the whole well stirred to obtain a uniform temperature. The temperature is then observed, from minute to minute, for four or five minutes, so as to determine its rate of change. The charge is then ignited by connecting one pole of the battery to the electrode F and touching the other pole to any part of the shell. The temperature is observed each minute until it begins to fall regularly, and then each minute for five minutes in order to ascertain the law of cooling. The agitator should be kept going constantly during the whole period of the observation. The shell is now removed from the water, the stop-cock R opened to let out the gas, and then the shell itself is opened. The shell should be rinsed out with distilled water to collect the acid formed during combustion. The amount of acid carried out with the escaping gas is negligible. The calorific power of the coal may now be calculated as follows:

Let Q = calorific power of coal.

Δ = observed rise of temperature.

x = correction for radiation.

P = weight of water taken in grammes.

P^1 = water equivalent of shell, appendages, and gas.

p = weight of HNO_3 found.

p' = weight of iron wire helix.

.23 calorie = heat of formation of 1 gramme of HNO_3.

1.6 calories = heat of combustion of 1 gramme of iron.

Then

$$Q = (\Delta + x)(P + P^1) - (0.23\,p + 1.6\,p').$$

EXAMPLE SHOWING METHOD OF CALCULATION.

1.042 grammes of coal was taken.

The calorimeter contained 2,276.6 grammes of water.

The water equivalent of apparatus = 490 grammes.

The pressure of oxygen = 25 atmospheres.

The law of variation of temperature in the calorimeter before combustion is expressed by

$$X_0 = O.$$

The law of variation during subsequent period is

$$X_1 = 27.46 - 27.395 = .065° \text{ C.}$$

Hence, during the period of combustion the system lost .065 degree by radiation.

The apparent variation of temperature is

$$27.460 - 24.855° = 2.605° \text{ C.}$$

Actual variation = 2.605° + .065° = 2.67° C.

The HNO_3 formed = .15 gramme.

And the weight of iron wire = .025 gramme.

Hence, heat of formation of HNO_3 = .15 × .23 = .0345 calorie.

And heat of combustion of wire = .025 × 1.6 = .04 calorie.

Heat of combustion of coal = 2.67 × (2,276.6 + 490)

= 7,386.6 calories.

7,386.6 — (.0345 + .04) = 7,386.53 calories

÷ 1.042 = 7,088.7 calories.

In our work with this instrument we tested five samples of coal, making five determinations with each sample.

The results were very satisfactory, the variations in the different determinations being less than usual in calorimetric tests, and can easily be accounted for by a very slight difference in the amount of slate or other incombustible substance contained in the different samples.

SAMPLE NO. 1. PENNSYLVANIA ANTHRACITE.

Average result of five determinations = 7,089.25 calorific power.
Highest " " " " = 7,115.66 " "
Lowest " " " " = 7,044.26 " "

SAMPLE NO. 2. SCRANTON COAL.

Highest result of five determinations = 7,970.16 calorific power.
Lowest " " " " = 7,612.86 " "
Average " " " " = 7,827.76 " "

SAMPLE NO. 3. WILKESBARRE COAL.

Average result of five determinations — 7,610.14 calorific power.
Highest " " " " — 7,673.8 " "
Lowest " " " " — 7,505.8 " "

SAMPLE NO. 4. BITUMINOUS COAL FROM CLEARFIELD REGION, PA.

Average result of five determinations — 8,127.88 calorific power.
Highest " " " — 8,170.4 " "
Lowest " " " — 8,057.4 " "

SAMPLE NO. 5. BITUMINOUS COAL FROM COLEMAN COUNTY, TEXAS.

Average result of five determinations — 6,766. calorific power.
Highest " " " — 6,793.6 " "
Lowest " " " — 6,720.3 " "

To test the reliability of the instrument four samples of willow charcoal were burned, with the following results:

Average result of five determinations — 7.973. calorific power.
Highest " " " — 7,975. " "
Lowest " " " — 7,971. " "

The great uniformity of these determinations shows this calorimeter to be a very accurate instrument. It also is very easily operated. As only about 40 minutes are required for each determination, it is evidently the quickest working calorimeter that has ever been invented.

THE PNEUMATIC PYROMETER.

BY EDWARD A. UEHLING, '77.

THE want of an accurate, reliable, and durable instrument for measuring high temperatures has long been felt, not only by scientists, but by engineers and metallurgists as well.

The pyrometers which have so far been available have either proved to be too delicate and difficult to manipulate for practical use, as, for instance, is the case with the electrical instruments, or inaccurate and unreliable, as are those depending on the expansion of metal rods, or too inconvenient and cumbersome, as are those depending on calorimetric methods.

The air pyrometer, although based upon the substance which possesses the ideal properties required for measuring the widest range of temperature with the greatest accuracy, has thus far given reliable results only in the hands of physicists.

It is not the object of this article to discuss the shortcomings and errors of the existing pyrometers; but, rather, to describe a new instrument, which is based on the fundamental laws of the flow of air, and makes use of a novel principle, by the aid of which all the difficulties attending the use of the existing air pyrometers are overcome.

The Pneumatic Pyrometer, which is the invention of the author, and has been brought to its present degree of perfection by Mr. Alfred Steinbart, a graduate of the University of Berlin, Germany, is based on the novel application of the law of flow of a perfect gas through two successive minute apertures. If these apertures form respectively the inlet and outlet of a chamber, then the tension in the chamber depends upon the difference of tem-

perature at which the air flows through the respective apertures into and out of the chamber.

Thus, if a current of air be caused to flow through the chamber by a constant suction, and be allowed to enter at one aperture at the temperature to be measured and be exhausted at the other at a constant normal temperature, then the tension of the air in the chamber will be a correct indication of the temperature to be determined.

The accompanying illustration represents the application of this principle to a pyrometer designed especially for continuously indicating the temperature of the blast used in the smelting of iron. The universal blast-furnace practice now is to heat the blast to from 1,200° to 1,600° Fahr., and it is very important to know at all times what the temperature of the blast is.

The principal object in using a highly-heated blast is to economize fuel; but the temperature of the blast also affects the chemical composition, and hence the quality, of the iron produced. Variation in the temperature of the blast therefore not only tends to increase the fuel consumption, but to prejudicially affect the quality of the iron, as well.

All modern blast furnaces are now equipped with firebrick stoves for heating the blast, and the every-day practice is to "change stoves" on time, usually at intervals of one hour. As a rule, at all well-managed plants, the temperature is taken with some form of portable pyrometer by the "stove men" at every change of the stoves, and recorded. The founder, however, has little faith in the record, and pays no attention to it. If the blow pipes show red he knows he has a good heat; if they are bright red the heat is very good; and, if the pipes are dark he stirs up the stove man, and if the furnace has made an "off-cast" of iron in consequence, the stove man is more or less severely hauled over the coals. "The heat was all right; see the records, 1,300 to 1,450 degrees." "D—— the record! black blow pipes and white iron show what your heat was. You did not have 1,000 degrees. I want 1,500 degrees." The "stove man"

now puts his entire energy into getting the heat up. Probably, when the founder comes around again he finds the blow pipes white-hot. His experience prompts him to inspect the stoves. He finds the combustion chambers dripping with the molten firebrick. "What do you mean by melting down the stoves?" "You wanted 1,500 degrees and I tried to get it." "Why, you have 1,700 degrees to 1,800 degrees." "No, sir; I have only 1,480 degrees; I just tried it." "White-hot blow pipes and melting down stoves on 1,480 degrees? Nonsense!" "But the pyrometer shows 1,480 degrees, and that is all I have to go by, and they want a record of the heat in the office." "That's all right enough for the office, but in future you watch the blow pipes and the combustion chambers, and don't pay any attention to the pyrometer when I give you orders."

This illustrates the state of the art as applied to blast-furnace practice; and other industries using high heats fare no better, if not worse. Confining ourselves to the blast furnace, we have the fact that 100 degrees of heat carried in by the blast is equivalent to something like 50 pounds of fuel per ton of iron filled at the top. Assuming the cost of coke at $2.50 per ton at furnace, and the average output at 150 tons per day, 100 degrees of heat in the blast would mean $\frac{2.50 \times 50}{2,000} = 6\frac{1}{4}$ cents per ton, or $9.32 per day, or over $2,500 a year. The difference in the market price between No. 1 and No. 3 foundry iron is about $1. Supposing the furnace makes only 50 tons of No. 3 iron, on account of irregular heat in blast, in a week, this would amount to $50 \times 52 = \$2,600$ a year. Both together, therefore, foot up to over $5,000, or 10 times the cost of an instrument such as illustrated and described below.

At the No. 2 furnace of the Sloss Iron and Steel Company, where the Pneumatic Pyrometer has now been in constant use for over four months, the following facts were revealed:

First. That no two stoves gave the same results, the best one losing 250 degrees in one hour, and the worst one the same amount in 35 minutes, and that changing by the watch at intervals, every

hour for instance, as is the usual practice, must give very irregular results.

Second. That while the records of temperature taken in the usual way varied between 1,350 and 1,450 degrees, the actual variation was between 1,150 and 1,650 degrees.

Third. That a dark blow pipe is not always an indication of low temperature. The pipe may be coated on the inside and indicate much less than the actual temperature of the blast.

Fourth. That the best portable pyrometers now available will vary from 50 to 150 degrees above or below the actual temperature measured.

Fifth. That with four good stoves the temperature of blast may be kept within 50 degrees of the heat desired.

Sixth. A dirty stove or a "short cut" in a stove is at once revealed by the incapacity of the latter for holding the heat.

It is, therefore, probably underrating the benefits derivable from the use of an accurate and continuous pyrometer to base its value on the figures given above.

The Pneumatic Pyrometer, as illustrated, is shown as attached to the hot-blast main of a blast furnace, and is especially designed for that purpose. It consists of a platinum tube B^3, Figs. 2 and 3, half an inch in diameter, and of sufficient length to extend very nearly through the lining of the hot-blast main, to the shell of which it is secured by the coupling *a*, and the gland *b*, the latter being secured to the flange *c*, which is bolted to the shell. Concentric, within the tube B^3, is placed a smaller platinum tube, *e e'*, three-sixteenths of an inch in diameter, which extends very close to the end of the tube B^3, and is held in position by the coupling *f*. The connection between *a* and *f* is provided with a branch *h*, to which is connected a filter B^1. The latter consists of a chamber, about 2 inches in diameter and 10 inches long, loosely filled with cotton. The inner pipe *e e'* continues by the pipe *i i* to the vessel C, and within this by the pipe *j* and worm *k k* to the coupling C^1, which is shown in detail, Fig. 4. The first small aperture is located at the end *e'* of

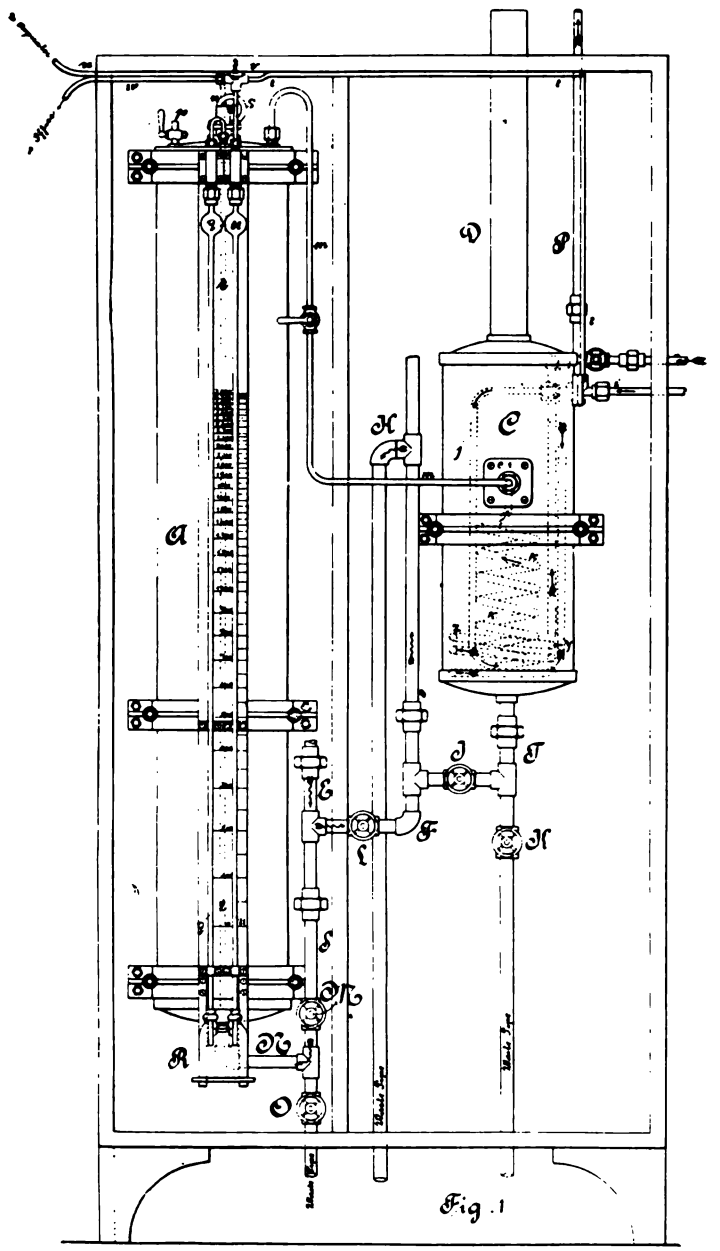
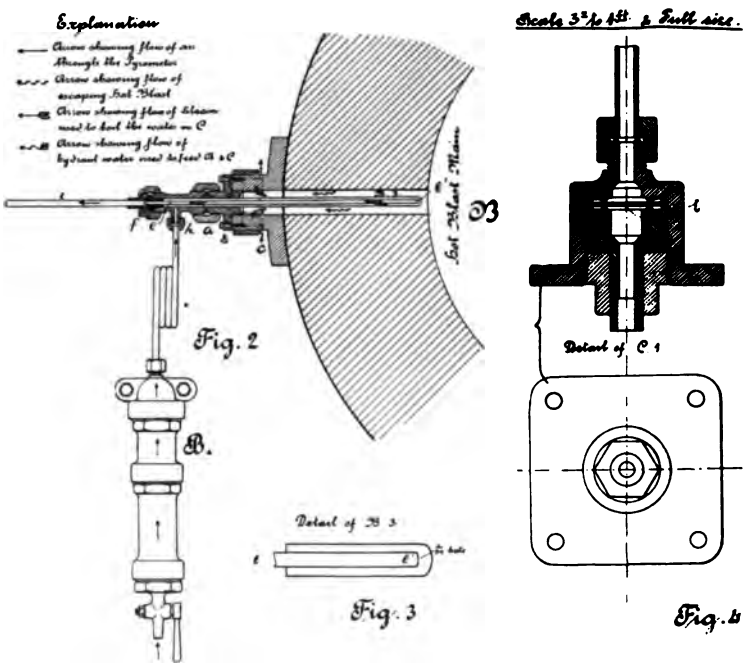


Fig. 1

the inner tube *e e'*, and the second aperture is located in the coupling C^1, as shown in Fig. 4 at *l*. From C^1 the tube continues by *m m* to the top of the chamber A. A also connects with an aspirator (not shown) by the pipe *n n*, and with the manometer *q q* by the bent tube *o*; it is further provided with a stop-cock *p* and with a tube *r r* which is open to the atmosphere at the upper end and reaches to within 3 inches of the bottom of the chamber A. The upper end



of *r r* passes through a stuffing box and is provided with a rack and pinion and wheel *s*, by which it may be raised or lowered. The pipe *i i* communicates through the capillary tube *t t t* with the manometer *u u* and may be prolonged by means of a T piece *v* and tube *w* to the office, or any other place or places where it may be necessary or desirable to indicate the temperatures to be measured. The manometer tubes *q q* and *u u* have their lower ends immersed

in colored water, contained in the reservoir R. The vessels A and C, which are made of brass tubes 7 inches in diameter, are respectively 4 feet 8 inches and 1 foot 6 inches long, are connected with the water supply pipe by the pipe connection E F T and E S N. C is the temperature regulator, and, with the valve K closed and L and I open, is kept filled with water to the level of the overflow H. The pipe and worm *x y z*, which is connected with the steam or hot-air main, continually keeps the water boiling; and, because C is open to the atmosphere through D, a constant temperature of 212° Fahr. is maintained. A is the suction regulator. By opening the petcock *p* and the valve M it is filled with water to the proper level. The tube *r r* must be immersed in the water in A exactly 4 feet, which can be readily done by the wheel S. By these means the essentials for exact determination of temperatures are supplied. The aspirator, capable of exhausting a somewhat greater volume of air than the small apertures will admit, is turned on; and the deficiency being supplied through the tube *r r* against a constant head of 4 feet of water, the suction at C^1, the second aperture, cannot vary appreciably above or below that point. By the manometer *q q* the suction may be at any moment observed, and will be found standing steadily at the point 4, so long as the tube *r r* extends into the water the proper depth.

The water in A very gradually evaporates, and as this occurs to an appreciable amount *r r* is lowered; when it has reached the bottom, it is again raised, and the waste is supplied through the valve M. This, in continual use, is found necessary about once a month.

The suction being applied, the air from the atmosphere enters through the filter B^1, where it is freed from dust, flows through *h* into the platinum tube B^3, where it assumes the temperature of the hot blast in the main B, at which temperature it enters the first aperture *c'* at the end of the tube, by which it returns and passes through *i i* into *j* and the worm *k k* located in the boiling water maintained in C. The temperature of melting ice, or any other

constant temperature, would answer as well. In its passage through the worm it assumes the constant normal temperature at which it flows through the second aperture located in C^1, as shown in the detailed sectional cut, Fig. 4, thence through *m m* into the regulator A, and from it, by the pipe *n n*, to the aspirator.

As already explained, the tension in the chamber or tube between the two apertures is a correct measure of the difference of temperature at which the air flows through each of them respectively; therefore the manometer *u u*, supplied with a proper index, and connected to the tube *i i* by the capillary tube *t t t*, will continuously and accurately indicate the temperature in B. The temperature manifesting itself as tension of a *continuous current* of air through *i i, j, k k*, the length of the capillary tube *t t t* does not affect the accuracy of the indications, neither does the number of manometers connected, so long as the connections are perfectly air-tight.

It is therefore quite feasible to indicate the temperature in as many places as may be desirable.

It is also immaterial, so far as the accuracy of the indications is concerned, at what distance from the place at which the temperature is to be measured the tension and temperature regulators A and C are located, so long as the area of the tube between the two apertures is sufficiently in excess of the area of the apertures. The latter is only one sixty-fourth of an inch in diameter, and can be made even less; and three-eighths inch pipe is ample for distances below 500 feet.

The pneumatic pyrometer can therefore readily be made semi-portable. By making the tube *i i* of sufficient length and flexibility, it would be quite feasible to transfer it from the smoke-box to the furnace or into any portion of a flue of a boiler which may be undergoing a test.

Changes of temperature of the air in the conduit between the apertures affect the accuracy of the indications only momentarily. *By virtue of the continuous flow of the air through the tube equilibrium*

is very soon established, and then the difference of temperature at which the air flows through the respective apertures determines the tension irrespective of its temperature while flowing from one aperture to the other. This property renders the pneumatic pyrometer available for measuring the temperature of very small areas as well as large ones; for instance, it is just as feasible to measure with it the temperature of the contents of a 10-gramme crucible as of 40 tons of molten steel contained in a huge ladle, and it can be made to indicate the temperature of the flame of a Bunsen burner as accurately as heat of the flame issuing from a converter.

The term, pyrometer, when applied to the above described instrument, is really a misnomer, for while it is capable of measuring temperatures up to where platinum ceases to be a solid, its range for low temperatures terminates only where air ceases to be a perfect gas. Its telemetric properties would seem to render it particularly applicable to cold-storage plants, and to all other industries where it is important to know the temperature of a place without going into it. The most important effect of the telemetric feature of this instrument will manifest itself in the moral force which it exerts on those who have to be relied upon to maintain the necessary or desired temperatures. It is one thing to give instructions that certain temperatures shall be maintained, and another to know that the orders are executed. If you have the means of knowing whether your orders have been faithfully carried out, they generally will be carried out, and *vice versa*.

One of the above described pyrometers has now been in continuous use for over four months, and has in that time frequently been subjected to heats above 2,000 degrees, and on one occasion to over 2,700 degrees without affecting its sensitiveness at the ordinary temperatures—viz.: 1,200 to 1,600 degrees.

THEORY AND PRACTICE IN TECHNICAL EDUCATION.

IN a recent address before the Institution of Electrical Engineers M. Alexander Siemens (than whom no one is better able to speak from personal experience and wide observation) said: "It is highly desirable that the teaching at engineering colleges should be confined to general principles as far as the applications of science are concerned, and that the student should become thoroughly well acquainted with the mental tools that are used in scientific investigation, such as mathematics, the general principles of chemistry, and of the branches of natural philosophy."

And further he says: "In most cases the conclusions of pure science have to be modified by practical considerations before a useful application can be produced."

Taking these two statements together, we will not be misled by the too unqualified assertions of either, and perceive that while insisting on the great importance of a training in general principles, Mr. Siemens does not intend to exclude instruction in the practical applications essential not only for their useful employment, but, as every experienced instructor also knows, equally essential for their full understanding and mental appropriation.

H. M.

EXTRACTS FROM THE ENGINEERING PRESS.

THE COMMERCIAL ELEMENT IN TECHNICAL EDUCATION.—"No more exasperating thing can occur to the young graduate coming forth with his brain filled with visions of thermodynamics, coefficients, neutral axes, radii of gyration, etc., than to be asked the price of a 6-inch pulley and have no idea of the answer nor know where to get the information; or to be asked the relative value of two different types of engines and to find, after having given their water consumption or their economy based thereon, that the relative value from a commercial standpoinf was wanted, or the cost per horse-power, day or year. I doubt if there are very many engineering schools in the country where the pupils are taught when to use a compound engine or when to use a condenser.

"Many an elaborate plan and many a well-laid scheme has fallen through because of the commercial element having been entirely neglected or not thoroughly understood. It will be argued, and justly so, that a student cannot cram his head with a mass of data whose value is as constantly fluctuating as the prices of different machines and their parts, but their value can be economically determined and retained, and the economical principles of the machine business can be readily taught. I would recommend a system or course of instruction, in shop and construction accounts and bookkeeping, together with the methods of determining the cost of construction, and practice in estimating; in bridge work, the method of determining the cost of a bridge, with the variation of price dependent upon the variation of span and weight of bridge: in shop work, shop accounts, piece work versus day work, arrangement of tools and buildings, with relation to the work to be done. It will not be possible to go into all the details of this subject, but the fundamental principles can be very readily covered.

"Let it ever be kept before the student that the profession of an engineer is essentially a commercial one, and that he must build no better than the exigencies of the case demand. He is a middle man between the producer of facts and the consumer; between the scientist and investigator and the business man, and that to suc-

ceed he must combine, to a certain extent, in his own person the qualities of both.

"The great names which have adorned the history of engineering were of those who, having the constructive faculty largely developed, built, as best they could, that which was required of them, often insecure, often crude, often abnormally expensive, and yet often better than they knew. To these men the problem was not so much what a structure would cost, but to build a bridge which would not fall down, a dock which would stand the buffets of ships and waves, a structure which would be enduring and serviceable alike. How well they have succeeded the monuments which they have left to us attest.

"It is with all reverence and humility that I thus speak of those who, by the boldness of their genius, astonished the world, and who set an example of problems solved and work done with facilities sufficiently inadequate to daunt the boldest at the present day. To these men the certainty and accuracy of their calculations as to the strength of a beam was of far more importance than its cost; the strength and distribution of the strains of a bridge of far more moment than the relative economy of different styles of trusses. To-day we are met by an entirely different set of conditions.

"One can buy, by the yard, strain sheets of bridges, roofs, and other framed structures of all kinds and for all conditions of service; for a few dollars a full set of designs can be had for different types of locomotives; the strength of materials has been carefully worked out, and books can be had for the asking, giving the strength of beams, girders, etc.; the efficiency of prime movers has been carefully determined, and the data thereon can be readily obtained. One does not now design a turbine wheel or a steam engine unless directly in that business, although one may thoroughly understand the subject; but, looking up the results of tests, one selects the engine best adapted to the work to be done, and goes to the manufacturer for the outfit complete. The question now asked is, not if a process can be devised for accomplishing certain results, but which of a number of methods is the best, and by the best is meant the most economical. Many an elaborate plan and many a well-laid scheme has fallen because of the commercial element having been entirely neglected or not thoroughly understood."—*Prof. L. S. Randolph, Stevens* '83, *in Cassier's Magazine for January.*

WASTEFUL USE OF EXHAUST STEAM.—"Economy from the use of exhaust steam from an engine for heating purposes has become so generally looked upon as a matter of course that it would seem to many almost like rank heresy to question the advisability, in any case, of utilizing so obviously valuable a waste product—in fact, to actually recommend throwing it away and substituting in its place live steam from a boiler.

"Every engineer knows that after steam has performed its legitimate function in a non-condensing engine and has there reached its limit of usefulness as a propelling agent behind the piston, it still possesses a very considerable amount of heat which can be profitably extracted in a variety of ways. For years, in fact, sermons were preached, and are still being preached, on the advantages to be derived from the several methods of turning this steam to some account, until, at last, owners of boilers and engines became educated up to that point where they recognized that by passing the exhaust through heating systems and feed-water heaters, instead of allowing it to escape directly into the open air, they could virtually get something for nothing.

"That in laying out such systems, however, there are qualifications to be observed which may make all the difference between gain and loss seems to have been overlooked in many instances, and, as a consequence, suggestive results can be found in numbers, strikingly showing that exhaust steam may sometimes be profitably allowed to go to waste."—*Albert Spies, Stevens* '81, *in Cassier's Magazine for January.*

LEGAL PROTECTION OF MENTAL PRODUCTS.—"An incident in the life of Crebillon was an early cause which led to the legal protection of the production of the mind. The invention in this instance related to literature; namely, the tragedy 'Catiline.' Crebillon, unfortunately, had several creditors, who attached his invention both as a book and as a play. Crebillon knew that in time the poetry which he had composed would be equivalent to many times his debts, and that it was, therefore, cruel that he should lose such valuable property. His petition is admirably worded, and as it could have been appropriately signed by any engineering inventor of this late day, it is reported in part below. The petition rehearses that the poem had been unknown, 'that it should not be allowed to class among seizable effects, the products

of the human mind; that if such a practice were permitted, those who had consecrated their vigils to the studies of literature, and who had made the greatest efforts to render themselves, by this means, useful to their country, would see themselves placed in the cruel predicament of not venturing to publish works, often precious and interesting to the State: that the greater part of those who devote themselves to literature require for the first wants of life those aids which they have a right to expect from their labors; and that it never has been suffered in France to seize the fees of lawyers and other persons of liberal professions.' The King, Louis XV., promptly issued a decree in May, 1749, awarding protection to literary inventors. In the proclamation it was declared that the productions of the mind are not among seizable effects. Later, in 1762, the same king issued decrees relating to inventions in general, the special object being to limit the term of privilege to fifteen years, so that an invention could not be left as perpetual property to descendants."—*Edward P. Thompson, Stevens* '78, *in Cassier's Magazine for January.*

A LARGE LOCOMOTIVE OF NEW DESIGN.—"The engine is to be capable of developing 2,000 horse-power; and, on the level, of attaining a speed of 100 miles per hour. The driving wheels are to be 12 feet in diameter, the cylinders 40, 28, and 13 inches by 30-inch stroke, and the boiler pressure 200 pounds per square inch. In front and rear of the large driving wheel there is to be a six-wheel bogie with 5-foot wheels. The boiler is to be on one side of the driving axle and the engines on the other side, with a three-throw crank axle. There is to be no tender, the water being carried in a tank underneath the floor of the engine-room, and the coal in the rear of the fire-box. The whole of the bearings are arranged inside the engine-room, and accessible when the engine is running. The driver's foot plate is to be in front, and will form a compartment by itself. The distance from London to Edinburgh is 500 miles, and the time taken, about 8¾ to nine hours, will be reduced to six hours. This locomotive was designed by Mr. Michael Reynolds, Standeford, England."—*Railway Engineer.*

CENTRIFUGAL STRAINS ON FLYWHEELS.—"A French engineer, M. Chaudy, proposes to overcome centrifugal strains on flywheels by making a sliding connection between spokes and rim by means

of stud bolts passed through smooth holes in the rim and screwed into flanges on the ends of the spokes."—*Railway Age.*

LARGE STEAM PIPES.—"The system instituted by the British Admiralty of winding all steam pipes over 8 inches in diameter with $\frac{3}{16}$-inch copper wire, thereby about doubling the bursting pressure, has within recent years, according to the *Engineer* (London), been adopted on many merchant steamers using high-pressure steam. The Italian naval authorities have adopted the system to some extent, and they find that, as with the wire-wound gun, wire of square section coiled round the pipe under tension adds enormously to the strength.

"A patented system of manufacturing steam pipes is at the present time being experimented with by a west of Scotland firm. It consists in using copper of the thinnest practical gauge to form the interior or core of the pipe, the body of the pipe proper being composed of steel wire wound closely round the core, and the interstices between the coils being filled in solid with copper by a system of copper electro-deposition. Pending this and other possible improvements on copper pipes, one result of past experience with these is to give an impetus to the use of lap-welded wrought-iron pipes. In the "Campania" and "Lucania" the main steam pipes are of this type, and experience with these so far bears out the contention of some engineers that for modern high pressures they are, on the whole, the best that can be used."—*Power.*

CASTING STEEL UNDER PRESSURE.—"A process which has been tried in this country on several occasions with varying degrees of non-success, of casting steel ingots under pressure developed by centrifugal force, has been in satisfactory operation in Sweden for about two years, according to *Stahl und Eisen.* The apparatus consists of an upright shaft carrying arms, each of which has a platform supporting ingot molds. The molds are upright when the shaft is at rest, but fly up to a horizontal position when set in rapid rotation. Pressure is developed in the direction of the length of the ingot, driving out gases and producing a solid casting of uniform composition. With a circumference of 67 feet and at a speed of 125 revolutions per minute, the pressure obtained is equal to 500 or 600 pounds per square inch."—*Railway Age.*

HARD-FACED STEEL CASTINGS.—"Among the other advances made in casting steel may be mentioned one for making a casting having one or more faces of steel much harder than the body of the casting. The process consists in lining such faces of the mold as will be adjacent to the parts of the casting which it is desired to harden, with a metallic alloy in a crushed or powdered state, capable of being melted and absorbed by the molten steel in contact with it, and of such a nature as to impart to the steel a hard face, or a face of such a composition as may be readily hardened. If it be desired that the casting shall have a permanently hard face, and be used for stamp dies, crusher jaws, and hammer dies, etc., ferro-manganese gives the best results. If it be desired to do machine work on the face, and make it extremely hard afterward, ferro-crome is most suitable. The fact that it is possible to produce a soft steel casting, having a face that can be hardened without causing the remainder of the casting to become brittle, will undoubtedly make it possible to use steel castings instead of chilled iron in many places with great advantage."—*H. L. Gantt, in Cassier's Magazine.*

"THE RAILWAY 'MARKS' invented by the Hungarian Minister, Lukaïs, will shortly be adopted on all Hungarian railways. For the future no traveler on Hungarian railways will be troubled to stand waiting at the ticket office for his ticket. He will be in a position to make out his ticket for himself. On a blank card he will write the name of the station from which he takes his departure, and that of the station he means to go to, and he will stick on to the remaining empty space on the card as many 'railway marks' as the journey will cost. The blank cards will be obtainable at all tobacco shops."—*London Daily News.*

"A NEW ELECTRICALLY-PROPELLED CARRIAGE is being introduced by M. Paul Pouchain, of Armentieres, France. The carriage will carry six persons. The electrical energy is supplied by a battery of 54 Dujardin accumulators. The motor is of the Rechinewski type, with an output of 2,000 watts. It is fixed in the center of the vehicle, and transmits its power by chain gearing to the driving wheel. According to the inventor the total weight of the carriage and equipment is about 1⅓ tons. One charge of the accumulators is sufficient for a journey of 44 miles at a speed of 10 miles per hour."—*Electricity.*

OBITUARY.

EDWARD BARRY WALL, eldest son of Prof. Edward Wall, of the Stevens Institute of Technology, died suddenly at Pittsburg, Pa., on April 1, of peritonitis, after undergoing an operation for appendicitis. He was taken ill on Saturday, and the operation was performed on Sunday afternoon, but he did not rally from the shock of the operation. The funeral took place from the Second Presbyterian Church, of Columbus, O., and he was buried beside his young wife, who died in August, 1893.

EDWARD BARRY WALL was born in Kingsborough, N. Y., on April 25, 1856.

Until he began his special preparation for the Stevens Institute, when he was fourteen years of age, his father, with the exception of a few months, had been his only instructor. This exception had been his attendance, when eleven years old, at the Polytechnic Institute of Brooklyn, which was interrupted by illness.

In April, 1870, he entered the school in Hoboken then called the Martha Institute. This name was changed to that of Stevens High School and subsequently to Stevens School, and forms the Preparatory Department of the Stevens Institute.

His English studies and Latin were continued in the Preparatory School, together with the branches of mathematics required for admission into the Institute. In 1872 he entered the class of '76, being then sixteen years of age.

The first two years of his connection with the Institute were not remarkable for application to his studies. His animal spirits were strong, and foot-ball and society had their attractions.

But with the beginning of his Junior year, he was now eighteen years old, a great change came over him. He gave up society completely. Not only were his evenings given to study, but he made all the use possible of the early mornings. The chief relaxation he allowed himself was foot-ball. He was on the team and played in the college contests. He was quick and cool, and although of no great weight, sufficiently strong to make an effective player.

In the experiments on boiler explosion, conducted at Sandy Hook by the U. S. Government in the summer of 1875, he worked as an assistant.

Toward the close of his Senior year his eyes became affected by his close application to study, and he was under treatment by an oculist for some time.

At the close of his college course he was elected Valedictorian of his class and Mr. J. Mather Wallis was elected Salutatorian. But, on account of some personal preferences, the duties were, with the permission of the class, exchanged, and Mr. WALL on commencement day delivered the Salutatory and Mr. Wallis the Valedictory. The congratulations which the speakers received at the time were well deserved, and the excellence of both addresses has often been spoken of since.

Immediately after his graduation he entered the service of the Pennsylvania Railroad Company in the car shops at Altoona.

He went through all the shops there as an ordinary apprentice, and, from the start, showed his purpose to add to his college education the knowledge which is to be gained only by the experience of the man who can lay aside, for the time, his books, put on his overalls, and, among the men that are to be under his direction, learn how work is to be done.

His ability to meet, and his determination to conquer, the problems that were before him, to "do with his might what his hands found to do," met a speedy reward in the recognition by his superior officers, that he was needed in a higher place.

From Altoona he was called to be Superintendent of Motive Power of the P. C. C. & St. L. R. R., an important part of the Pennsylvania system. In this position he spent ten years, and manifested such an ability to meet the problems of his profession, such singular power to deal with men, and such loyalty to his company, that he received the confidence not only of his superior officers, but also of the men that were under his control; and he was looked upon by railroad men everywhere as one of the brightest men in the profession.

About a year ago he was selected to go to Chicago to represent the Pennsylvania Railroad interests at the World's Fair, and a large share of the success of that feature belongs to him. He was chosen as one of the Jury of Awards in the Transportation Department of the Fair. At the close of the Fair he was promoted to the position of Assistant to the General Manager of the Pennsylvania Lines West of Pittsburg. The next step would have been to that of one of the vice-presidents of the road, and there is no doubt but that he would have occupied that place in the near future.

The following extract from the report of the President of the P. R. R. will show the estimate that was put upon him by those who were associated with him in his work.

"While engaged in the preparation of this report, death has again deprived the company of the services of one of its most promising and valuable officers, Mr. EDWARD B. WALL, who, on March 1, 1893, was appointed Assistant to the First Vice-President, and transferred to Chicago, with the general supervision of traffic questions arising at that point, and particularly in connection with the Columbian Exposition. This office having been abolished in January, 1894, Mr. WALL was appointed Assistant to the General Manager, with special supervision of the operations of the Purchasing Department. His long connection with the Motive Power Department and general knowledge of transportation had thoroughly fitted him for discharge of responsible duties, and his sudden death, on April 1, has entailed on our company a loss which cannot be too highly regretted.

"By order of the Board,

"G. B. ROBERTS, *President.*"

In addition to his work with the Pennsylvania Railroad, Mr. WALL was often called upon as an expert on mechanical questions, and was prominently identified with other organizations in the line of his profession. He was for a number of years President of the Master Car Builders' Association, and an active member of the Society of Mechanical Engineers.

He always took a lively interest in his *Alma Mater*, and year after year assisted its young graduates in obtaining positions in which they could start on their engineering career, and many of them have justified the wisdom of his selection.

He was President of the Alumni Association of the Stevens Institute, and was the representative of the Alumni on the Board of Trustees of the Institute at the time of his death.

The esteem in which he was held by his associates was manifested at his funeral. The shops all over the system were closed, and the general offices in Columbus; the honorary pall-bearers were the Vice-Presidents and general officers of the railroad, and the actual pall-bearers were the Superintendent of Motive Power and the Master Mechanics of the Pennsylvania Lines West of Pittsburg.

Although it had been requested that no flowers be sent, there were some of his subordinates that insisted upon thus testifying their regard. From the Brotherhood of Locomotive Engineers, an organization supposed to be antagonistic to their superior officers, came a large floral keystone, the emblem of the company, on which, in purple violets, was the significant legend:

" Pennsylvania Lines,
" Apprentice 1876.
" Assistant to
" General Manager
" 1894."

It condensed in four lines the lesson of his life to every man on the road.

In June, 1891, Mr. WALL married Fannie, daughter of Gen. John G. Mitchell, of Columbus, Ohio.

She died in August, 1893, leaving a son, Edward Barry Wall, surviving her. His brief married life was an ideally happy one.

Much of Mr. WALL's success and rapid promotion was due not merely to his intellectual ability, but to those qualities of heart and mind which are summed up in the word *character*.

The old Roman motto, "*Humani nihil alienum*," was never better exemplified in human character than it was in his. He was in touch with every man that he met, from the highest to the lowest. Two instances, among many, will serve to illustrate this. While he was in Altoona, just starting in his apprentice career, a young man was tried and convicted of a crime, and sentenced to a term in State's prison. Something in the testimony appealed to Mr. WALL as indicating that the man was not so great a criminal as the judgment of the court would imply, and he determined to reach out to him a helping hand. And, so three times a week, he went down to that man's cell and taught him arithmetic and American history. He brought him out of that cell feeling that a man of character and position had cared for him and when "he was in prison had visited him." Years afterward the man whose life he had redeemed sent him a large seal ring, a signet attesting the words "forasmuch as you have done it unto one of these you have done it unto me." One of the officers of the road, speaking of this characteristic, said: "When WALL and myself went around on a tour of inspection I would nod to the men; but I remember, last week, an old switch-tender to whom I had nodded, he touched his hat and I passed on. But WALL stopped, and, in his hearty way, said, 'Well, how are you getting along now?' The old switch-tender stepped forward, told him how he and his family were, and took to him, as if he felt him to be his friend."

This feeling was not assumed, but with every one with whom he came in contact he felt, and had the rare gift of showing that he felt, that there was a tie between them. His gift of humor, kindly

and genial, void of any satire or cynicism, was often the magic wand with which he found the solution of a trying situation. Men came to him full of their grievances, in arms against what they conceived to be his antagonistic position toward them. He heard their grievances, giving them full opportunity to state their case, and then solved the whole question with a joke that sent them away in good humor. To those who knew him best this quality of his lent a great charm to his conversation. Under his genial influence men showed their inner selves and furnished him with a fund of anecdote illustrating life and character.

This is the lesson of his life to young men: Power lies not in place or position by which the world measures success, but in character; and of all qualities of character, "the greatest of these is love."

RESOLUTIONS ON THE DEATH OF EDWARD B. WALL, ADOPTED BY THE EXECUTIVE COMMITTEE OF STEVENS ALUMNI ASSOCIATION.

The Executive Committee of the Alumni Association of the Stevens Institute of Technology, unanimously adopted the following set of resolutions on the death of ex-President of the Alumni Association and Alumni Trustee, EDWARD BARRY WALL, of the class of '76:

"*Whereas*, It has pleased Almighty God, in his Divine Wisdom, to call from our midst our honored and highly respected member, EDWARD BARRY WALL, whose sterling worth not only endeared him to all of us, but inspired us with feelings of admiration and esteem; and

"*Whereas*, Since we feel our loss deeply, we wish to place on record our appreciation of the virtues and amiable qualities of a true and genial companion, a zealous and able member of the engineering profession, and one who always manifested the greatest interest in the welfare of our Association; therefore be it

"*Resolved*, That while testifying to his honorable record as a man and his valuable work as an engineer, we deeply deplore his premature and sudden death, and extend our heartfelt sympathy and condolence to his bereaved family, though knowing full well that words do not truly express the respect and esteem which were accorded to our deceased friend and professional brother by all who knew him; and be it

"*Resolved*, That as a mark of esteem these resolutions be spread on the minutes of the Alumni Association and printed in THE STEVENS INDICATOR; also that copies of them be transmitted to his sorrowing family, and to the Board of Trustees of the Stevens Institute of Technology."

H. VAN ATTA, *President.*

P. E. RAQUÉ, *Corresponding Secretary.*

MIDWINTER MEETING OF THE ALUMNI ASSOCIATION.

THE midwinter meeting of the Alumni Association was held in the School Lecture Hall on February 20, and was called to order by the President, Mr. Van Atta.

The minutes of the previous meeting, at which the new Constitution had been adopted, were read, and upon motion duly made and seconded, were unanimously approved.

The Treasurer of the Association, Professor Bristol, reported that the funds in hand exceeded $1,200.

Professor Riesenberger, Acting Treasurer of the Alumni Building Fund, reported the amount of the fund, including interest, as $9,400.

Mr. Van Atta, as Chairman of the Executive Committee, reported that the affairs of the Association were in excellent shape.

These reports, upon motion duly made and seconded, were accepted.

The President then announced that the principal object of the meeting was social enjoyment, and that in furtherance of this aim it became his pleasing duty to call upon members for addresses on subjects of interest to all. He called upon Mr. A. R. Wolff, '76, to speak of "Stevens at the World's Fair." Mr. Wolff endeavored to convince the meeting that he was so closely occupied in the examination of exhibits, during his ten days' stay at the Fair, that he did not see anybody, not even Stevens Alumni, but casually remarked that during the hours spent with his friend Denton in the Midway Plaisance, they thought they recognized, in the streets of Cairo, the worthy President of the Association.

Dr. Morton, in explaining "Why Stevens had no Authorized Representation at the Fair," stated that the product of the Institute

is engineers, and that to gather the graduates from all parts of the known world, in camp at Chicago, was impracticable. The influence of Stevens graduates was evident throughout the Fair, in the exhibits and in the work of the important committees.

Mr. E. B. Wall was asked to speak of "Lubrication," and replied that, generally speaking, the difference in results following the use of various brands of lubricants was due to the men using them rather than to qualities of the oils employed; adding, in lighter vein, that lubrication had been known to work wonders in overcoming imposing obstructions to great enterprises.

Professor Wood, speaking to "Stevens at the Next World's Fair," alluded to possible achievements in the future, and predicted a distinguished pre-eminence for Stevens men in those days.

"Peculiarities of Stevens Graduates" was handled in happy vein by Professor Denton, who was frequently interrupted by bursts of laughter and applause.

The speeches were interspersed with music by the Glee, Mandolin, and Banjo Clubs of the Institute, who were present by invitation, and whose selections were highly appreciated. At the close Mr. Wall, in moving a vote of thanks to the musical societies, stated that the rendering of the song "Mechanical Engineer" reminded him, and doubtless many more present, of happy times twenty years ago, and asked that it be sung again and that all join in the chorus. It was done with a will; and lips, strange to the tune for nearly a generation, caught up the refrain, and sang to a close the formal part of this meeting of Mechanical Engineers.

Under Professor Bristol's supervision, well-laden tables were then wheeled into the hall, and groups of friends, some long parted, discussed at the same time their varied fortunes and an appetizing collation.

LIST OF MEMBERS IN ATTENDANCE.

President Henry Morton.
Prof. De Volson Wood.
" A. R. Leeds.
" C. F. Krœh.
" J. E. Denton, '75.
" W. E. Geyer, '77.
Ass't Prof. A. Riesenberger, '76.
" W. H. Bristol, '84.
" D. S. Jacobus, '84.
" S. D. Graydon, '75.
" Robt. M. Anderson, '87.
A. Sorge, '75.
G. C. Henning, '76.
Wm. Kent, '76.
P. E. Raqué, '76.
A. P. Trautwein, '76.
A. R. Wolff, '76.
E. B. Wall, '76.
A. G. Brinkerhoff, '77.
F. E. Idell, '77.
R. S. Kursheedt, '80.
D. Woodman, '80.
R. Dixon, '81.
H. Van Atta, '81.
F. E. Fraentzel, '83.
M. McNaughton, '83.
W. L. Lyall, '84.
W. S. Tuttle, '84.
E. Burhorn, '85.
R. Norris, '85.
J. H. Bates, '87.
J. H. Cuntz, '87.
W. S. Dix, '87.
J. D. Flack, '87.
F. Moeller, '87.
A. H. Schlessinger, '87.
H. A. Bang, '88.
R. Beyer, '88.
G. Campbell, '88.
G. Dinkel, '88.
P. Doty, '88.
S. V. Hoffman, '88.
J. V. L. Pierson, '88.
F. Uhlenhaut, '88.
H. S. Wynkoop, '88.
W. B. Yereance, '88.
L. B. Bonnet, '89.
J. Eastwood, '89.
W. W. Jackson, '89.
P. C. Graupner, '89.
F. Gubleman, '89.
W. M. Hill, '89.
W. D. Hoxie, '89.
R. C. Olyphant, '89.
J. R. Onderdonk, '89.
W. M. Farrar, '90.
E. W. Frazar, '90.
D. C. Harvey, '90.
E. H. Peabody, '90.
S. F. Smith, '90.
E. H. Whitlock, '90.
W. S. Ackerman, '91.
A. P. Boller, '91.
A. Dow, '91.
L. H. Nettleton, '91.
A. Post, '91.
H. W. Smith, '91.
A. R. Hake, '92.
H. W. Jackson, '92.
H. Harrison, '92.
F. E. Law, '92.
H. D. Reed, '92.
F. L. Waefelaer, '92.
O. C. Whitney, '92.
H. H. Adams, '93.
B. G. Braine, '93.
A. G. Brookfield, '93.
O. G. Dale, '93.
F. D. Furman, '93.
W. Hunter, '93.
H. Kopp, '93.
T. S. Leonhard, '93.
E. D. Lewis, '93.
M. O. Slocum, '93.
G. L. Wall, '93.

MEMBERS OF THE MUSICAL SOCIETIES PRESENT.

'94 H. D. Coleman.
E. B. Gallaher.
J. W. Gilmore.
E. Guade.
R. E. Hall.
A. Kollstede.
E. D. Mathey.
W. D. Pierson.
W. E. Shoemaker.
R. W. Smith.
'95 D. D. Barnum.
S. Cooper.
E. M. Harrison.
'95 F. N. MacVeety.
F. N. Taff.
'96 F. M. Bennet.
R. E. Bruckner.
E. Campbell.
J. P. Evertz.
G. Kollstede.
H. C. Messimer.
P. D. Wagoner.
'97 H. C. Mathey.
R. L. Messimer.
A. M. Orr, Jr.
A. de Los Smith.

ATHLETICS.

THE ANNUAL MEETING of the Intercollegiate Athletic Association was held at the Fifth Avenue Hotel, New York, on Saturday, February 24. The colleges represented were Amherst, Brown, C. C. N. Y., Columbia, Cornell, Fordham, Georgetown, Harvard, Lafayette, University of the City of New York, Princeton, Rutgers, Stevens, Swarthmore, Union, University of Pennsylvania, Wesleyan, and Yale. The delegates from Stevens were Messrs. G. S. Montgomery and A. C. Sumner.

The report of the Treasurer for the past year gave for the year's receipts, $5,025.92; expenditures, $3,614.89. The balance, $1,411.03, will be equally divided among those colleges which sent competitors to last year's game.

It was decided to hold future bicycle races under the rules of the League of American Wheelmen, and the weight of the 16-pound hammer was reduced so that the handle and sphere together shall weigh only 16 pounds. Owing to the games being heretofore prolonged to such a late hour, it was decided to hold the first heat of the 440-yard run in the morning, and also the field contests, until the competitors are reduced to five in each event.

The following officers were elected: President, W. H. Wheelright, Harvard; Vice-President, Mr. Bond, Swarthmore; Secretary, D. P. Andrews, Cornell; Treasurer, L. Tracy, Fordham. Executive Committee: Wade, Yale; Mackey, U. P.; Runquist, C. C. N. Y.; Crossett, U. N. Y.

LACROSSE.

The annual meeting of the Intercollegiate Lacrosse Association was held at the Lafayette Hotel, Philadelphia, on Saturday, February 24. In the absence of President Penniman, of Johns Hopkins, Mr. Corbett, of Stevens, presided.

The delegates from Lehigh were Messrs. Buell and Ordway; from Johns Hopkins, Messrs. Cameron and Plaisance; from Stevens, Messrs. Corbett, Kellogg, and Hall. The championship banner for 1893 was awarded to Lehigh. The rule forbidding spikes on shoes was amended to read: "No metal strip or spike." An effort of Johns Hopkins to reduce the size of the ball used was defeated, on the ground that the ball being so small already any reduction would make it less easily seen. Running the guard over the top of the stick was allowed, it being understood that no pocket is to be made.

Stevens *vs.* Johns Hopkins, at Hoboken, May 12. The schedule of games was arranged as follows:

Hopkins *vs.* Lehigh, at Baltimore, May 18.

Stevens *vs.* Lehigh, at Bethlehem, May 30.

The officers for the ensuing year are: President, Ordway, of Lehigh; Vice-President, Cameron, of Johns Hopkins; Secretary, Corbett, of Stevens; Executive Committee: Hall, of Stevens; Coleman, of Lehigh; Plaisance, of Johns Hopkins.

Kingsley L. Martin, Captain of the championship team of 1892, is writing a series of articles on lacrosse for the *Stevens Life*, which will undoubtedly prove instructive, especially to new players.

Arrangements are being made for several games in and about Hoboken, the first of which will occur during the second week in April.

FIELD GAMES.

Preparatory to the joint games with Rutgers, field games will be held at the Hoboken grounds two or three weeks in advance. From among the men entered in these games the teams for the Rutgers games and the Intercollegiate games will be selected. In order to stimulate interest, medals will be given to the winners, and the *Stevens Life* will award a banner to the class scoring the greatest number of points.

BASKET BALL.

A Basket Ball team was organized early in the winter term to play with the team of the Orange Athletic Club. The first game was played in the tennis building of that club on Saturaday evening, February 10. The game is similar to lacrosse, each team guarding a basket or net into which it is the object of their opponents to throw a foot-ball. Tackling and running with or kicking the ball are not allowed. Stevens defeated Orange with the score: Stevens, 4; Orange, 0. The teams lined up as follows:

Stevens.		*Orange.*
Coyne	Goal	Vaughan.
Kemble	Point	Doldt.
Corbett	Cover point	Hiscoe.
Maynard	First defense	Lloyd.
Cuming	Center	Munn.
Kellogg	First attack	Wallis.
Fielder	Outside home	Gibson.
MacCord	Inside home	Taylor.

INSTITUTE NOTES.

AT THE CONVOCATION of Queen's University, Kingston, Ontario, on April 25, 1894, the degree of LL. D. was conferred upon Charles Macdonald, Trustee of Stevens Institute, and Vice-President American Society of Civil Engineers, also upon His Excellency the Governor-General of Canada, the Earl of Aberdeen, upon the Honorable Joly de Lobiniere, ex-Prime Minister of Quebec, and upon the President of Toronto University.

Professor Williamson, in presenting Mr. Macdonald, said:

"Mr. Macdonald is a Canadian by birth, being the lineal descendant of Joel Stone, the founder, and of Charles Macdonald, who largely shared in the early upbuilding of Gananoque, now the busy seat of varied manufacturing industries.

"His early education was derived chiefly from the grammar school, then an adjunct to Queen's University, of which two of his younger brothers became graduates. After a brief attendance at a private instruction in the principles of engineering with one of its professors, and some preliminary experience as an assistant in the surveys then begun for the Grand Trunk Railway, he entered upon his professional course of three years in the Rensselaer Technical Institute, Troy, in the State of New York, and was graduated from that institution as Civil Engineer. He has since devoted himself chiefly to the laying out of railways and more particularly to the construction of railway bridges, very many of which have been built from his skillful designs and under his superintendence. Among his other works, he is distinguished as the successful designer, against a number of competitors from other countries, of a bridge over the river Hawkesbury, in Australia, which he built for the Government of New South Wales, and which is specially remarkable as being constructed on deeper foundations than any other in the world.

"He is now engaged in a project for bridging the Hudson River at New York, involving a span of 2,200 feet."

The Chancellor, Mr. Sandford Fleming, in announcing the degree, remarked that he had passed over the Hawkesbury bridge a few months ago, little thinking that he should soon have so agreeable a duty to perform.

In reply Mr. Macdonald said:

"*Mr. Chancellor, Ladies and Gentlemen:*

I accept the degree of Doctor of Laws, with which I have been invested ...en's University, with a profound sense of appreciation of the honor ...ed upon me.

But, Sir, I should be wanting in the commonest feelings of gratitude were I to fail at this time to make full and frank acknowledgment of my indebtedness to the institution which has thus honored me, for an early training, which has been the foundation upon which I have ever since been endeavoring to erect a superstructure wherewith to bridge over the varying complications of a busy life.

If I have been in any measure successful in this, the credit is largely due to the unyielding character of that foundation, which was composed of carefully-selected materials, laid on in regular courses, and thoroughly well hammered in.

I was one of the first students at the preparatory school, adjoining what was then called Queen's College, occupying very unpretentious buildings at the corner of William and Barry Streets, known as Lot 24—and a very bad lot it was in the latter forties.

The Head Master of the school was the late Rev. John Campbell, one of the early graduates of Queen's.

Of the professors then in control, the only one now remaining, I believe, is the perennial Dr. Williamson, who then, as now, ruled supreme in mathematics, and is ever the enthusiastic investigator and lucid interpreter of the laws which Nature has established for the governance of the universe.

These were the infant days of a university which to-day has attained so exalted a position among the institutions of learning throughout all this land.

Well may the worthy men who have labored diligently and so well to bring about this result feel gratified with their work.

Well may the people of the Dominion represented by your Excellency the Governor-General, gladly join in doing honor to Queen's University. But, above all, should her children, whether here in exuberant presence, or scattered abroad over the four quarters of the globe, rejoice to be able to renew again and again the assurance of their loyalty and of their devotion to the mother who gave them intellectual birth."

Professor Krœh read a paper upon "How Shall We Learn Modern Languages?" at the Educational Conference held under the auspices of the Committee on Education of the New York yearly meeting of the Religious Society of Friends in New York City on March 17, 1894. The author maintained that the only proper basis of elementary instruction in modern language is spoken language. The discussion of the paper was opened by Dr. E. H. Magill, of Swarthmore College.

The Franklin Institute, Philadelphia, has recently awarded the Edward Longstreth Medal of Merit to Professor Bristol for his "Recording Gauge for Extremely Low Pressures." Accompanying the medal is a report in which the committee states that: "The Institute, through a subcommittee appointed for the purpose, has carefully tested the sample gauge submitted to them, in comparison with a U-tube water gauge, and finds it extremely sensitive and promptly and freely responsive to all changes of

pressure. The recording arrangement is very simple, easily adjusted, and performs its functions satisfactorily." A series of comparative tests with the water gauge gave readings showing "a degree of accuracy which is quite remarkable, when the stiffness of metallic plates is compared with the perfect mobility of water. The gauge therefore seems to be perfectly adapted to the recording of very low pressures."

(Signed by) JOSEPH W. WILSON, *President.*
WILLIAM H. WAHL, *Secretary.*

A PAPER has been prepared for presentation at the Montreal meeting of the American Society of Mechanical Engineers by Professors Denton and Jacobus, and R. H. Rice, '85, on results of experimental measurement of the 1,600 horse-power cross-compound engine at the mill of the Bristol Manufacturing Company, New Bedford, Mass. It will constitute an important contribution to the vexed question of the value of the steam jacket on Corliss mill engines.

AMONG THE TESTS recently engaging the attention of the Department of Tests have been an elaborate investigation of the cost of operating street cars with Waddell storage batteries on Second Avenue, New York; also an economy test of a plant of 2,000 horse-power of Manning boilers at the Bristol Manufacturing Company's mill at New Bedford, Mass., undertaken for the maker, the Bigelow Manufacturing Company, of New Haven, Conn. The latter test covered the performance of the boilers, both with bituminous coal and anthracite, over a wide range in capacity, and at boiler pressures of 125 to 150 pounds.

PROFESSOR DENTON has of late been conducting a series of experiments with a view to securing reliable data for the solution of the problem of securing a large increase of speed in ferry boats for the New York and Staten Island Ferry.

They involve tests of the screw boats "Bremen" and "Netherland," and of the feathering paddle boat, "Robert Garrett," in ferry service and over a measured distance, also under a variety of conditions. Among the data thus obtained is the difference in efficiency of a feathering paddle wheel when in forward and in back action, which had never before been determined.

PROFESSOR JACOBUS has investigated the influence of compression on the water consumption in a 50 horse-power, single, non-condensing Ball & Wood engine, located at the Institute for the purpose of experiments. These are, we believe, the first measurements on the influence of this factor on the distribution of steam that have ever been made, and the results will be presented by Professor Jacobus at the June meeting of the American Society of Mechanical Engineers.

THE RELATIVE HEATING EFFICIENCY per square foot of surface in "extended surface" and in "plain surface" radiators has been a recent subject of investigation by the Department of Tests, comparative tests of the two classes of surfaces being involved.

THE AMERICAN METER COMPANY has forwarded a cubic foot bottle to the Department of Tests for accurate calibration. The work is being done in the "even temperature room."

PROFESSOR BRISTOL has perfected a thermometer and pyrometer for recording temperatures common in dry kilns, japanning ovens, etc., an account of which will be submitted in a paper to be read at the June meeting of the Society of Mechanical Engineers.

PROFESSOR KRŒH has published the third book, "How to Think in Spanish," in his series on the "Living Method" of learning modern languages. The Method has excited lively interest on the part of educators, and teachers call on Professor Krœh at the Institute to note its application and results.

THE AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION has published notice that there will be two scholarships available at Stevens Institute next September, to which sons of members or of deceased members are eligible.

THE DEPARTMENT OF TESTS has recently completed a series of tests of two forms of centrifugal blowers. In these tests the quantity of air discharged was determined by the use of a Pitot tube, as well as by anemometer readings. The results obtained by the two methods were found to agree with each other.

A WORKING MODEL of an absorption ammonia refrigerating machine has been constructed for the use of students who will make tests upon it during the Preliminary Term. In this machine all ammonia joints are sealed, there being no valve packing boxes or other appliances in which leakage of ammonia can occur.

THE MOST MARKED IMPROVEMENT in the surroundings of the Institute, since the erection of the new School building, has resulted from the removal of the fence, this spring, from around the college grounds.

A low bluestone curb has been substituted, which is not noticeable at a short distance, and the effect of the change is to apparently make the park an extension of the Institute grounds.

THE JUNIOR BALL was held at the Lenox Lyceum on Friday, April 6. The committee, comprising Messrs. Sumner, Cuming, Kemble, Cooper, Stuart, and Taff, worthily merited the cordial commendation accorded them for their excellent arrangement of every detail of decoration, music, floor management, and supper, which secured a delightful evening to all who participated in the Junior Ball of '94.

INSTITUTE PERSONALS.

It is our endeavor to notice under this heading such items of news affecting graduates of the Institute as may interest their classmates and friends among the Alumni. We are indebted to a few members for regular or frequent contributions of items, and wish to make it known that the co-operation of all is most desirable, and will be appreciated. MANAGING EDITOR.

'75.

ADOLPH SORGE has removed to Chicago, where he has accepted the position of Assistant Superintendent at the works of Fraser & Chalmers.

'76.

WILLIAM KENT'S address is Passaic, N. J.

EUGENE VAIL was one of the American exhibitors at the Salon of the Champs Elysées this season.

The New York *Herald* of April 30 makes the following mention of his picture:

Mr. Eugene Vail, who was born in France, of New York parents, displays a landscape, "Soir d'Automne à Etaples." It represents the bridge at Etaples on an autumn evening. Two figures, a woman and a child, are slowly returning home toward the village.

'77.

E. A. UEHLING recently spent several weeks in New York, arranging for the manufacture of his Pneumatic Pyrometer, which is fully described in this number of the INDICATOR, wherewith to fill orders already received from the Bethlehem Iron Company, the Sloss Steel and Iron Company, and the Poughkeepsie Iron Company, and in prospect from other prominent concerns. He will soon return to his home in Birmingham, Ala., but contemplates traveling through the iron regions to introduce his invention. The following notice has appeared in some of the leading technical journals, bearing testimony to the value of his services to the company he has been connected with for the past three years:

"About three years ago Mr. Uehling took charge of the furnaces of the Sloss Steel and Iron Company, of Birmingham, Ala. (which from various causes were in a very bad shape), with the view of reconstructing them in accordance with modern practice. This work has been at last accomplished by dint of unremitting labor, and Mr. Uehling now retires with the highest testimonials from the Board of Managers. The office of Furnace Manager, which was created for Mr. Uehling's occupancy, has

been annulled on his retirement, the management considering that their business can now be carried on without such expert assistance."

'78.

J. R. STEPHENS sailed for England last month on his way to Johannesburg, South African Republic, where he will take charge of the development of mining property. His address is care of Barnato Brothers, Johannesburg, South African Republic.

'79.

J. H. LONGSTREET is proprietor of the Riverview Iron Works, Bordentown, N. J.

'81.

ALEXANDER C. HUMPHREYS has resigned his position as General Superintendent of the United Gas Improvement Company, the resignation to take effect August 1, and intends to devote some months in England to the growing interests there of his firm, Humphreys & Glascow, and upon his return to start an office of the firm, probably in New York City.

The announcement of Mr. Humphreys' action comes too late for the full notice in this issue, merited by an event of so great interest to so large a number of Stevens Alumni.

The July INDICATOR will contain an account of matters connected with Mr. Humphreys' model management of the business of the United Gas Improvement Company, which the occasion has caused to become public, and which it is the pleasing province of this journal to record.

'82.

CHARLES W. SCRIBNER is Instructor in Mechanical Engineering in the University of Pennsylvania, Philadelphia, Pa.

'83.

E. DUQUE ESTRADA has been elected to membership in the American Society of Mechanical Engineers.

'84.

JAMES S. ALDEN, whose health has become impaired, is traveling in Florida.

DABNEY H. MAURY, Jr., is Superintendent of the Peoria Water Company, Peoria, Ill.

CHARLES F. PARKER is Engineer for Charles W. Clinton, 32 Nassau Street, New York City.

GEORGE F. SANDT is Secretary and Treasurer of the Electrical and Mechanical Engineering and Trading Company, with office at 39–41 Cortlandt Street, New York City.

KENNETH TORRANCE has been promoted from Junior to full membership in the American Society of Mechanical Engineers.

'85.

W. H. WADE has recently completed the construction of a 2,000,000 Lowe water gas plant for the city of Belfast, Ireland. Humphreys, '81, & Glascow, '85, are the contractors.

'86.

CHARLES RUSSELL COLLINS is Inspector of Manufacturing, The United Gas Improvement Company, Drexel Building, Philadelphia, Pa.

WILLIAM W. RANDOLPH has been transferred by the United Gas Improvement Company from Des Moines, Iowa, to the Philadelphia office, Drexel Building, Philadelphia, Pa.

E. D. SELF delivered an address in April before the New York Academy of Science, upon "The Utilization of Bassassachic Falls, Mexico," which will be printed in the School of Mines *Quarterly* for July.

Mr. Self was employed to report upon the practicability of utilizing the falls, and of transmitting the power a distance of 11 miles for mining operations, which involved a personal inspection and measurement of the falls.

'87.

JAMES H. BATES is Assistant Engineer and Draughtsman for C. J. Bates & Co., 126 Liberty Street, New York City.

J. A. P. CRISFIELD, is Superintendent of the Mutual Gas Light Company, Savannah, Ga. This company is controlled by the United Gas Improvement Company, of Philadelphia.

JOSEPH A. MCELROY is Assistant Engineer in the Field Engineering Company, Central Building, New York City. His former position was that of draughtsman in the same company.

'88.

GORDON CAMPBELL is Purchasing Agent of the Consolidated Traction Company, Jersey City, N. J.

T. A. VAN DER WILLIGEN is in the employ of Mr. C. L. Strobel, builder of bridges, turntables, etc., Home Insurance Building, Chicago, Ill.

WILLIAM B. YEREANCE has applied for membership in the American Society of Mechanical Engineers.

'89.

DAVID H. GILDERSLEEVE is Mechanical Engineer for the Yaryan Company, *Times* Building, New York City.

N. HILLER. In the interest of the Hendrick Manufacturing Company, with which he has been connected since his graduation, Mr. Hiller, in February, undertook for a year the management at Los Angeles of the ice-making plant recently completed there under his supervision.

GEORGE G. PLYER is Special Agent for the Lancashire Insurance Company, New York City.

'90.

CHARLES J. EVERETT, Jr., is Manager of the Lowville Iron Works Company, manufacturers of centrifugal pumps and paper machinery, and for G. W. Renton, successor to Turret Valve Company. His office is in the Havemeyer Building, Room 409, 26 Cortlandt Street, New York City.

WILLIAM M. FARRAR'S address is 624 East Nineteenth Street, New York City.

D. C. HARVEY is in the employ of the New York Fidelity and Casualty Company.

HARRY P. JONES is in the frog, switch, and signal department of the Pennsylvania Steel Company, Steelton, Pa.

E. H. PEABODY, formerly draughtsman for the Babcock & Wilcox Company, 29 Cortlandt Street, New York City, is now in the testing department of that company.

FREDERIC THUMAN has spent the past year in Copenhagen, London, Brussels, and Glasgow, testing Russian petroleum and Scotch shale oils for their value as gas-making oils in the Lowe apparatus.

E. H. WHITLOCK has established himself as consulting engineer at 175 Plum Street, Cincinnati, O.

A. R. WHITNEY, Jr., has applied for Junior membership in the American Society of Mechanical Engineers.

'91.

A. P. BOLLER is assistant to the New York representative of the Snow Steam Pump Works, 106 Liberty Street, New York City.

WILLIAM S. BUVINGER is Chief Draughtsman for the Thomas Carlin's Engine Works, Allegheny, Pa.

BENJAMIN W. CARLL is Special Inspector for the American Insurance Company, 115 Broadway, New York City.

F. L. JOUBERT is connected with John H. Murphy's Iron Works, New Orleans, La.

FRED. A. MUSCHENHEIM is with the Western Electric Company, Chicago, Ill.

J. A. NORCROSS is stationed at Glasgow, Scotland, in the interest of Humphreys & Glascow.

H. W. SMITH is in the employ of the Kinsman Block System Company, Room 511 Central Building, corner Liberty and West Streets, New York City.

J. T. WALLIS is in the shops of the Pennsylvania Railroad, West Philadelphia, Pa.

'92.

A. J. POST, Jr., was married on April 11 at St. Matthew's Church, Jersey City, to Miss Mary Abbett, daughter of ex-Governor Leon Abbett.

H. L. SHEPARD, with George Shepard & Son, manufacturers of hatters' goods, is located at Bethel, Conn.

A. SHIEBLER'S address is now care of B. F. Sturtevant Company, 135 North Third Street, Philadelphia, Pa.

LOUIS WAEFELAER, Jr., is with Carl H. Schultz, Mineral Spring Waters, 430-440 First Avenue, New York City.

'93.

W. B. AXFORD is associated with his father under the firm name of W. H. Axford & Son, heavy building contractors and engineers, 310 Eighth Street, Jersey City, N. J.

ALVIN V. BOODY is the General Assistant in the Elmira Illuminating Company, Elmira, N. Y.

A. B. BROOKFIELD is in the employ of Baker & Co., Newark, N. J.

HERBERT B. COOK is with the Pencoyd Iron Works, Pencoyd, Pa.

WILLIAM Y. DEAR is salesman for the Jersey City Printing Company, 37 Montgomery Street, Jersey City, N. J.

JAMES A. GOLDSMITH is in the empioy of Hess, Goldsmith & Co., silk manufacturers, Paterson, N. J.

BEATTIE A. INGLIS is in the employ of the Florida Manufacturing Company and of the Dunnellon Phosphate Company. The former company's works are located at Madison, Fla., and the latter at Rockwell, Fla.

GEORGE LLOYD WALL is with the Norwich Union Fire Insurance Society, New York City.

A. B. LORD is employed as chemist by the National Lead Company, at the factory in Brooklyn.

ANSON G. WILBOR, sanitary engineer, has his office in Room 54, Tweddle Building, Albany, N. Y.

SPECIAL.

D. D. A. OUTCALT has been granted letters patent for an improved automatic electric weighing machine.

H. S. VERLEY at the close of the second term returned to Jamaica, W. I., where his parents reside. He is superintending the installation of electric plants upon the island, and is assisted by Gordon M. Maynard.

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TESTS OF AUTOMATIC FIRE SPRINKLER HEADS.

BY PROFESSOR D. S. JACOBUS.

ABOUT ten years ago the New York Board of Fire Underwriters submitted several automatic fire sprinkler heads to President Morton for comparative tests. Since that time all the sprinkler heads, and systems connected with the same, that have been considered by the Board have been examined by President Morton, and it has been the pleasant duty of the writer to execute the tests and prepare reports on the same.

The first tests were much less complete than those which are now made, for the reason that as time passed on, and the action of the sprinklers could be noted after several years of actual service, various defects were developed, which were not foreseen or anticipated. The present tests are made to cover, as nearly as possible, all those features in which defects have been noticed, and for this reason are much more elaborate, and the requirements of a successful head are much more severe than in the first tests.

The object of this paper is to present in detail the tests now made on a sprinkler head, and to describe the various qualities which a reliable head should possess.

Before describing the tests it will be well to consider the way in which sprinkler heads are used:

There are two classes of fire-extinguishing systems which use automatic sprinkler heads, one called the "dry-pipe," and the other the "wet-pipe" system. In a dry-pipe system there is no water in the pipes to which the sprinklers are attached until a sprinkler head, or an independent plug or other device, is released by the action of heat so as to operate a main valve, which admits water to the system of piping. In some systems the compressed air is contained in the main system of piping, and is released by the opening of one or more of the sprinkler heads. In another system the compressed air is carried in a separate system of piping of small diameter, from which it is released in case of fire by means of special fusible plugs. Still another method which has been used for operating the main valve, is to employ fusible links attached to wires, which are under a tensile stress and which will allow weights to fall and open the main valve if any one of the links is melted. In the wet-pipe system, water, or some non-freezing liquid, fills the entire system of pipes and acts directly against the sprinkler heads.

The object of a dry-pipe system, or one employing a non-freezing compound, is to prevent freezing in the pipes leading to the sprinkler heads. In either of these systems, however, a main valve must be employed between the water tank and the system of piping, and the addition of this valve adds a piece of mechanism which must operate in case of fire, and which if it should fail would render the whole system useless.

Another disadvantage of a compressed air dry-pipe system is that the water is longer in reaching the fire than in the case of a wet-pipe system. In a wet-pipe system the water is thrown from the sprinklers the moment they open, whereas, in a compressed air dry-pipe system, the air has to escape from the pipes before the main valve opens to admit water to the system of piping, and after the main valve opens the water has to fill the pipes before reaching the sprinkler head. The time between the opening of a sprinkler head and the appearance of water at the head varies with the size of the plant. In large plants the time required is from one to five

minutes, according to the location of the sprinkler head, and in some cases a longer time than this is required.

The wet-pipe system, on account of its greater reliability, is therefore used in all cases where there is no danger from freezing.

In a dry-pipe system the heads are usually placed in an upright position above the pipes, so that all the water may be drained from the system after the operation of the main valve and before re-charging with air. If placed in a pendent position the general form of sprinkler heads will hold a small amount of water after the pipes have been drained, and this water may cause trouble by freezing. Sediment and rust from the pipe also tend to collect in the heads when placed in a pendent position. Special forms of sprinkler heads have been designed to overcome this difficulty. In these the valve is placed at or near to the top of the screw thread so that no water or sediment can collect over the head after the pipes are drained.

In a wet-pipe system, the heads are usually placed in a pendent position; in this case they are just as efficient as when placed upright, and the piping may be hung directly against the ceiling, whereas with vertical heads the piping must be hung some distance below the ceiling in order to allow the heads to distribute properly.

The main valves of dry-pipe systems should be inspected and tested at regular intervals. We have tested and noted the effect of time on many of the best forms of such main valves, but will confine ourselves in the present paper simply to the tests and qualities to be sought after in the sprinkler heads.

The defects which are developed in sprinkler heads when subjected to a long-continued use are as follows:

1. The valve may stick to the seat after the fusible solder releasing device has fallen apart and released the valve.

2. The releasing device may not fall apart after the fusible solder has melted so that the valve will not be released.

3. The heads may open of their own accord without the application of heat.

The defect of sticking at the valve seat was first noticed in heads where gutta percha washers were used at the valve faces. The gutta percha became, in some cases, cemented firmly against the seat so that the sprinklers would not open at ordinary pressures. The same defect was found to exist when a lead washer was employed against a brass seat. A copper disk was then introduced between the lead washer and the valve face, and this was found to add greatly to the reliability of the head.

Various other materials have been employed in place of the lead washer and the copper disk. In some heads a ground brass valve is used against a brass seat, and in others glass valves are used.

A very small force will hold the valve against the seat, so that sticking at the valve seat must be especially guarded against. For example, if a sprinkler on the top floor of a building has a head of 18 feet of water acting on it, the pressure acting on the sprinkler is about eight pounds per square inch. The nozzle of many sprinkler heads is about one-half inch in diameter, or one-fifth of an inch in area, so that the pressure produced on the valve by the water is about 1½ pounds. A small amount of corrosion, or collection of pasty material at the valve seat, will often cement the valve to the seat so that it will not open at this low pressure. To overcome this difficulty sprinklers are made with flexible diaphragm valve seats, which spring outward when the releasing device opens, and thus tend to force the valve away from the seat. Springs have also been introduced to force the valve from the seat. In some sprinkler heads a steel clock spring is employed to turn a screw, which forces open the valve. In a head of recent design a helical tempered steel spring, specially protected from corrosion, is placed so as to force the valve from its seat. A steel spring protected from corrosion is preferable to a brass one, as experience has shown that the elasticity of brass deteriorates much more rapidly than that of steel.

The second defect, or failure of the releasing device, was developed in heads which relied in a great measure on the elasticity of the

brass frame, or other stiff brass pieces, to throw apart the releasing device. In some forms of heads the cohesion of the fusible solder after melting in the releasing device is sufficient to prevent it falling apart, provided the head is adjusted so that there is but little pressure brought to bear against the valve.

In several heads which we have tested the force acting on the valve could be adjusted so that no leakage would occur at 40 pounds pressure per square inch, and this force would be insufficient to throw apart the releasing device after the fusible solder had melted. If such a head is screwed up tightly it will operate perfectly when new, for there is then sufficient force acting on the releasing device from the elastic force developed by strain in the frame to throw it apart; but tests of heads of this class which were connected to a water system for five years show that about 50 per cent. fail to operate at the end of this time, and also show that the severe strain brought to bear on the brass frame diminishes so that there is practically just enough strain remaining after a long period of use to prevent leakage at ordinary pressures. In a sprinkler where this difficulty is apprehended we therefore release the strain on the valve until it is just tight at ordinary water pressures, and a failure to operate when adjusted in this way is considered a fatal defect.

Springs have been used between the valve and the releasing device to assist in throwing apart the releasing device. When a spring is employed to force the valve from its seat it serves the double purpose of preventing sticking at the seat, and of throwing apart the releasing device.

The third difficulty, or that of opening without the application of heat, is one which has proved a serious defect in several forms of heads. In general it may be stated that the greater the strain which is brought to bear on the solder joint the more reliable the sprinkler will be in case of fire; whereas, this strain will tend to cause the sprinkler to open of its own accord, and thus produce water damage. The fusible solder employed will gradually yield if subjected to excessive strain, so that in some forms of heads, poorly

designed in this respect, we found that nearly all opened of their own accord when connected to short pipes filled with water, which were mounted so as to be free from any jar or shock. A severe water hammer will tend to cause trouble in this respect in a head of rigid construction, but this effect has been exaggerated in the minds of many observers. A special test was made on a head which it was feared would give trouble in this respect by mounting it in a special apparatus where a severe water hammer was produced. One thousand blows failed to cause leakage, and produced no apparent yielding at the solder joint.

Having considered the various causes of failure we will describe the tests which are now made when a new form of head is submitted to us. These tests are for:

1. Reliability of action and sensitiveness.

2. Distribution and rate of flow in the open air and under flat and joisted ceilings.

3. Durability in which the sprinklers are connected to short pipes which are filled with water. These tests are made in order to note if releasing device will open of its own accord, and to determine if corrosion will cause the valve to stick to the seat.

RELIABILITY OF ACTION AND SENSITIVENESS.

Reliability of action is of far more importance than the sensitiveness of a sprinkler head. The main feature of a sprinkler head is that it shall operate with certainty in case of fire. To make tests on this point the sprinklers are heated in an oven, and the reliability of action noted at the same time that the sensitiveness is determined.

A second series of tests consists in applying a flame at intervals directly to the sprinkler heads. This is done in order to copy the effect of a sudden fire where there are drafts of air. In the second series of tests a gas burner that gives a large heating flame which will completely envelop the sprinkler head, is held for an

instant below the sprinkler, and then removed; the operation being repeated until the head opens. This test is a severe one, and sprinklers which will open correctly in an oven will sometimes fail when subjected to an intermittent flame. The main cause of failure in this test is the "starting" of the solder joint so as to allow the sprinkler to leak in such a way as to cool the solder joint and prevent further opening.

The tests for sensitiveness are made in the special testing oven shown in Fig. 1. A description of this oven was given at the

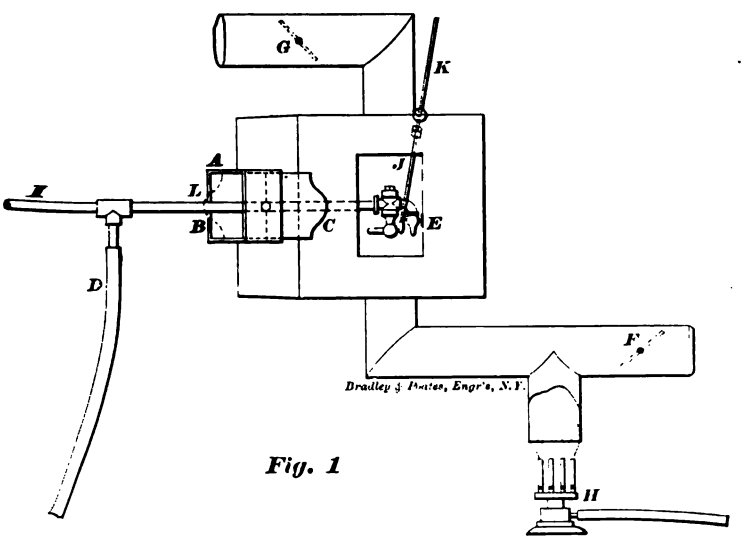


Fig. 1

meeting of the American Association for the Advancement of Science, held at Madison, Wis., August, 1893, and was published in the *American Machinist* for January 11, 1894. It consists of a sheet-iron box 2 feet high, 2 feet long, and 1 foot wide. The air in the oven is first brought to a given constant temperature, and the sprinkler is then introduced. The time required to set off the sprinkler head is noted by means of a stop-watch. The sprinkler

is placed in the small chamber A at the side of the oven. The chamber A is separated from the oven by means of two sliding doors B and C, and the air in it is at about the temperature of the room. Before placing the sprinkler in the chamber A the water in the pipe leading to it is brought to the temperature of 70° Fahr. in order that the cooling action of the pipe shall be the same in each test. To accomplish this the pipe is heated above 70° Fahr., and is gradually brought down to this temperature by allowing the heated water to escape through the petcock at E, so that it is replaced by colder water from the supply tank. The temperature of the room is maintained at about 70° Fahr. The oven is heated to a temperature of 300° Fahr. by means of the Bunsen burner H. It is preserved at this point by regulating the damper F. The damper G is employed to maintain an approximately equal flow of hot air through the oven. There are a series of deflector plates so arranged that the hot air entering the oven is distributed so as to cause the temperature to be nearly equal at all points near the center of the oven. The temperature is measured by the thermometer J, which is held by the rod K that passes through an adjusting arrangement, which allows the bulb to be set at the same height and near the solder joint of the sprinkler head.

The sprinkler is introduced in the oven by opening the sliding doors B and C, and moving the pipe I L, which is held in adjustable guides, until the sprinkler reaches the desired position at the center of the oven.

There is an outside cover to the box A, that is not shown in the sketch, which prevents the hot air in the oven from escaping on opening the sliding doors B and C at the time the sprinkler is introduced. The water from the supply tank passes through the hose D.

The results given by this oven are quite uniform, provided the heads are set so that there is the same amount of stress on the solder joint of each. If some of the heads, however, are tightened up harder than others, and there is a great difference in the stress

brought to bear on the solder joint, the time required to open will vary, being the least in those in which the stress on the solder joint is the greatest. The time required to open a sprinkler head of average sensitiveness is two minutes, the oven being at the constant temperature of 300 degrees, and the sprinkler and pipes leading to the same at 70 degrees before introducing the sprinkler in the oven. The most sensitive head we have tested required slightly less than one minute at 300° Fahr., and the least sensitive of the standard forms five minutes.

In developing this form of oven many experiments were made to test the reliability of the results obtained. Solder joint pieces were made of a uniform size, and were attached to a special sprinkler head where they were subjected to a given tension by means of a spring and weight device. This special head was placed in the oven, and the time to melt the solder joint noted for both upright and pendent positions.

In the first experiments the time required to melt the solder joint in the special head varied if the conditions were slightly altered. In the present form of oven the special head gave accordant results.

A sprinkler head placed in an upright position in the oven will operate more quickly than one in a pendent position, because the cooling action of the pipe tends to produce a downward current of air about the sprinkler head, which slightly retards the action when the sprinkler is attached to the underside of the pipe.

The oven shown in Fig. 1 was adopted after experiments on many other forms.

In the first tests for the sensitiveness of sprinkler heads they were placed in an oven which was heated up slowly, and the time required to open them, and the temperature of the air, as registered by a mercury thermometer, was recorded. This did not give strictly comparative results, because the temperature of the air was in excess of that recorded by the thermometer, and variations in the rates of heating caused different times and temperatures. To

overcome the difficulty resulting from the temperature of the air being higher than that of the thermometer, the oven was heated quickly up to a certain temperature, and then slowly until the sprinkler head opened. The error of the thermometer was thus reduced to about 2° or 4° Fahr.

Tests were made in this way for some time, as the sensitiveness of a sprinkler was not considered to be of as great importance as many other features which must be embodied in a successful head, and as the method gave results that would indicate if the sprinklers were about of the average sensitiveness it was exact enough for all practical purposes.

Various defects are sometimes found in the construction of the heads. The valve will sometimes fall in such a way as to obstruct the outflow and thus affect the distribution. In others a loose piece of the releasing device may fall in such a way as to catch underneath the valve and prevent it from opening to the full extent. A collection of sawdust, or other foreign material, on the deflector may also prevent the full opening of the valve. The heads should be of such a form that the most severe corrosive action will not cause a failure.

DISTRIBUTION AND RATE OF FLOW.

The apparatus for determining the distribution and rate of flow* consists of an open tank so mounted that the water level is 10 feet above a ¾-inch horizontal pipe leading to the sprinkler head. A large valve is placed directly under the tank, and from this valve a 1-inch ordinary steam pipe leads to the ¾-inch horizontal pipe, which is 10 feet long.

The object of employing the particular lengths and diameters of pipes given above was to introduce the element of friction of the

* A general description of this apparatus was given by the writer in the discussion of a paper by Mr. A. F. Nagle, *Transactions* A. S. M. E., Vol. XI., p. 709, 1890.

pipes which lead to sprinklers when placed in actual service. In order to eliminate differences of friction that might occur in the pipes leading to the sprinkler head, one of the first tests made on the apparatus was to carefully determine the rate of flow, on a sprinkler head having an orifice turned accurately to size, and in which the deflector was so low that any deformation in the same would not alter the rate of flow. This standard head should, therefore, always give the same rate of flow, provided the friction of the pipes does not alter by an appreciable amount.

Before making any of the succeeding tests the rate of flow of the standard head was re-determined, and allowances were made for slight differences, or the pipes were replaced whenever a large difference was found.

All tests on the rate of flow that we have made may be, therefore, compared directly with each other.

The diameter of outlet of the standard sprinkler is 0.555 inch, and it discharges 1.54 cubic feet of water per minute at 10 feet head.

The New York Board of Fire Underwriters require that with 10 feet water head the distribution 8 feet below a sprinkler head shall be over a circle at least 10 feet in diameter, that the diameter 6 inches above shall be 8 feet or over when tested in the open air, and that the rate of flow shall be at least 1 cubic foot per minute.

To measure the distribution 6 inches above the head, a graduated straight-edge is employed. The observer stands at the same level as the straight-edge, and can readily observe the diameter of the circle spread over.

In addition to tests in the open air, tests are made to show distribution under joisted and flat ceilings.

Tests are made at high water pressures as well as that equivalent to 10 feet head.

Sprinklers distributing water in a proper way, under 10 feet head and at 25 pounds pressure per square inch, are shown in Figs. 2, 3, 4, and 5. It will be seen that the water is divided in streams

FIG. 2.—Sprinkler distributing water properly. Head of water, 10 feet.

FIG. 3.—Sprinkler distributing water properly. Pressure of water, 25 pounds per square inch.

Fig. 4.—Sprinkler distributing water properly. Head of water, 10 feet.

Fig. 5.—Sprinkler *distributing water properly.* Pressure of water, 25 pounds per square inch.

and large drops, which are thrown upward as well as downward from the deflector. The upward portion tends, in a measure, to protect the ceiling above the head, whereas, the presence of a ceiling will not seriously affect the distribution.

Figures 6 and 7 show the distribution of a head in which too much water is thrown upward. When placed under a ceiling the distribution will not be satisfactory.

FIG. 6.—Sprinkler throwing too much water upward. Head of water, 10 feet.

Figures 8 and 9 show the distribution of a head in which the water is thrown in an irregular way.

Figures 10 and 11 show another poor form of distribution. In this the water is thrown in the form of an umbrella, so that there but little water thrown directly under the head. Still other

defects are sometimes found, such as a division of the water into two distinct portions by the side bars of the frame of the sprinkler head.

A sprinkler which divides the water in a fine spray as shown in Figs. 2 and 3 is not as desirable as one in which the water is thrown in large drops and streams as shown in Figs. 4 and 5, because a draft of air will more seriously affect the distribution when the water

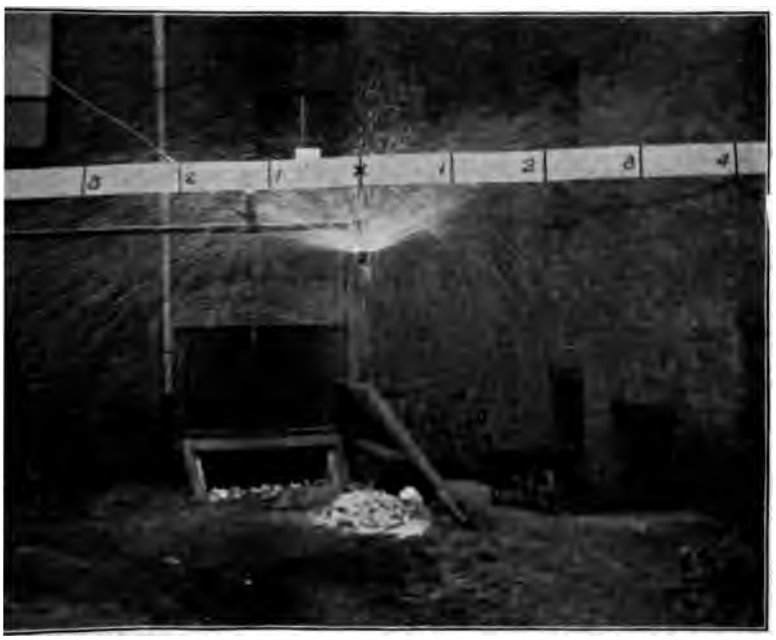
FIG. 7.—Sprinkler throwing too much water upward. Pressure of water, 25 pounds per square inch.

is thrown in the form of a spray than it will when the water is thrown in large drops or streams.

The scale shown in the figures above the sprinklers is marked in feet. In Fig. 4 the scale was not painted white, as were all the others, and therefore it appears darker.

FIG. 8.—Sprinkler distributing water irregularly. Head of water, 10 feet.

FIG. 9.—Sprinkler distributing water irregularly. Pressure of water, 25 pounds per square inch.



nkler distributing poorly. Too little water being thrown directly under the head.
Head of water, 10 feet.

prinkler distributing poorly. *Too little water being thrown directly under the head.*
Pressure of water, 25 pounds per square inch.

DURABILITY TESTS EXTENDING OVER A CONSIDERABLE PERIOD OF TIME.

After making the tests already described on a new form of sprinkler head, a number are connected to short lengths of pipe, which are filled with water and with salt and water. These pipes are mounted where they are free from jars or shocks.

The object of this test is, as has been before stated, to determine if the sprinklers will open of their own accord, and also to note the effect of corrosion in producing sticking of the valve to its seat. The most practical test in this line is to observe the action of sprinklers after they have been in service for several years, and many such tests have been made.

The time tests above mentioned have been of great service in determining the action of special forms of heads, many of which have never been put to practical use; and the information derived therefrom has been of use in predicting the action of time on new forms of sprinkler heads.

COMPARISON OF INSULATING MATERIALS FOR COLD STORAGE.

BY RUDOLPH RIEGE, '93, AND FRANK L. PARKER, '93.

IN the construction of insulating walls and partitions for refrigerators and cold storage and freezing rooms, judging from numerous references on the subject, there has been a marked difference in practice, which difference can only be accounted for by the absence of true knowledge as to the relative values of the substances used for insulation, and also as to the outlay required for such insulating materials. The relative heat-conducting capacities of many insulating materials in the market are published by those interested in their sale, and, though the results of scientific tests as to conductivity are honestly set forth, they are often twisted and distorted in a manner entirely misleading to the purchaser. To make a series of reliable tests requires much time and patience. Hence, in order to arrive at accurate data, we have only been able to deal with a couple of substances, which, while cheap, at the same time afford a fairly good insulation. Most of the tests on the transmission of heat of materials suitable for refrigerating insulation have been made on a comparison based on equal thicknesses of the materials tested. It should be borne in mind, however, that most all heat-protective walls and partitions are generally built of a combination of insulating materials, as that of wood, air, space, and paper, or wood with some filling (as charcoal, shavings, or cork), and that varying thicknesses of these materials are used. Such queries as, "Is air space better than shavings?" or, "Is charcoal as good as cork?" and "Will lampblack beat sawdust?" etc., are often encountered, and should be met with the question, "What combination is desired, what thicknesses are to be used, the service

expected of it, and the cost of the insulation per square foot?" after which an intelligent answer can be given.

The cooling agent used in the refrigerator, whether it be ice or some form of mechanical refrigeration, has a threefold duty to perform after the box has once been cooled to its required temperature: 1. To cool the material placed in the box to the required box temperature. 2. To cool the air admitted by the openings or other apertures of the box. 3. To take up the heat that finds its way through the insulation. The third duty is generally the greatest; that is, the largest proportion of the refrigerative agent is used to absorb the heat which comes through the insulation, and this proportion is not, as is often supposed, in ratio to the cubical contents of the box, but in proportion to the square feet of surface exposed. The square feet of surface exposed grows rapidly less in proportion to the cubical feet contained, as the cubical contents increase, and, while the cost of taking care of conducted heat per cubical foot diminishes as the size of the box increases, it remains the same per square foot, the cost of the insulation being, of course, as to the square foot of surface.

A series of experiments on the non-conducting qualities for coverings for steam pipes was made by Prof. John M. Ordway, and published in the *Transactions* of the American Society of Mechanical Engineers. The experiments were made by covering a pipe (through which steam was passed) with different materials inclosed in a calorimeter, and then noticing the different amounts of steam condensed, and so arriving at a decision as to their respective merits. With other than compact, solid substances, the results were of course complex, as the closeness of contact of the particles of solid matter, their specific conducting power, and the friction exerted by the particles on the included air, all had to be depended upon. The fewer the points of contact of the solid grains and the more rigidly the air was held by the interstices, the less opportunity afforded for the transmission of heat respectively

nduction and by convection. When air is allowed to move

about in a closed space it can transfer much heat, unless the source of heat be from the top, so that the usefulness of mere air space has been much overestimated, and it is seldom they can be so placed as to render much service.

When more and more organic fibre is crowded into a given space, the thickness of the stratum remaining the same, the transmissive power appears to be diminished until a certain limit is reached, beyond which an increase occurs. The reason is probably that the mobility of the air has been brought to a minimum, and the proper conducting power of the fibre begins to act more decidedly. Hence this is a strong argument against the use of materials in the form of paste to be plastered on, as the compression of non-fibrous matters, as lampblack, fossil meal, magnesia, and zinc white, increases the conducting power in a marked degree. The quantity of the substance remaining the same, compression, which lessens the thickness of a covering, decreases the heat-retaining power in no small degree, a matter of much practical and economic importance.

The great difference between the efficiency of the same absolute bulk of chalk and black lead is probably due to the fact that the air slides much more freely over the smooth particles of the latter, and it is not unlikely that the smoothness of the soapy mineral fibre of asbestos is also the cause of the difference of efficiency between it and wool.

Very porous and light bricks confine the heat much better than those which are hard burned, but they should be kept dry, as the presence of moisture in a non-conducting body greatly impairs its usefulness.

Also the high efficiency of light non-conductors is owing mostly to the imprisoned air, which really occupies all but a small fraction of the space, and the more quiet the air is kept the better is the effect. Professor Ordway draws the conclusion from his experiments that air is a good non-conductor only so long as it is confined by the interstices of the material from circulating in currents around

the box. Concluding he says: "The obvious moral is: Use any non-conductor light and thick rather than dense and thin."

In refrigerating buildings air spaces between the partitions are generally considered among the best insulating means, provided that such air spaces are hermetically sealed from the atmosphere both inside and outside of the refrigerating rooms, the idea being that such air will possess an average temperature of the inside and outside atmospheres and that, therefore, each of the insulating walls is only exposed to the fraction of the prevailing difference of temperatures. As to the thickness of this air space, experiments with steam have shown that a quarter of an inch is as good as an inch, yet in practice they are seldom made less than 3 inches. Again, it has been found that radiant heat has the remarkable property of passing through *moderate* thicknesses of air without appreciable loss, or heating the air sensibly, so that in ordinary cases air cannot be heated directly by radiant heat but only by contact with heated bodies.

In calculating the rate of flow of heat through the refrigerating wall, it should be remembered that it is in proportion to the difference of temperatures existing on each side of the wall, and that the greater this difference the greater will be the amount of heat transferred through insulators of the same value. Hence the unit of conductive value is the amount of heat which passes through a unit surface in unit time at unit difference of temperature, and the value of an insulating wall should be based on the number of British thermal units passing per day per square foot of surface per degree Fahrenheit of difference of temperature on each side of the insulation.

Let N = the number of heat units penetrating 1 square foot of surface for every degree difference of temperature.

c = a co-efficient depending upon the heat-conducting ability of the material composing the walls.

$t - t'$ = difference of temperature between the inside and outside walls.

e = thickness in feet of the insulating material.

Then $N = \frac{c\,(t - t')}{e}$ = the number of heat units absorbed for every square foot of surface.

If the walls are built of different materials whose respective thicknesses are e, e', e'', e''', etc., and the corresponding co-efficients are c, c', c'', c''', etc., then the formula becomes:

$$N = \frac{(t - t')}{\frac{e}{c} + \frac{e'}{c'} + \frac{e''}{c''} + \frac{e'''}{c'''}}$$

Some of the values for c found by Mr. Rassbach and published in *Ice and Refrigeration* are herewith given:

Pine wood.....c	= .084	Sawdust..... c	= .0437
Mineral wool	= .068	Charcoal (powdered).	= .053
Granulated cork.....	= .0537	Cotton	= .0268
Wood ashes.....	= .0403	Soft paper felting...	= .0228

For solid brick walls the values of $\frac{c}{e}$ and $\frac{e}{c}$ are:

Thickness of wall, inches	9	13	18	22
$\frac{c}{e}$.....	0.395	0.298	0.2375	0.204
$\frac{e}{c}$.....	2.53	3.355	4.21	4.9

For air-tight double floors of wood properly filled underneath so that the circulation of the atmosphere is excluded, and for ceilings of similar construction, $\frac{c}{e} = .082$.

In testing the value of insulating walls or partitions there should be some means of determining accurately the rate of flow of the heat through the wall or partition. This can be done with accuracy in several different ways, though in the following tests the apparatus used consisted essentially of a wooden box, a tin box, thermometers, and a pail to catch the drip from the ice the agent used in cooling. The boxes were respectively 44 inches and 25 inches cube on the inside, the tin box containing the ice to be melted. The wooden box was made of ⅞-inch white pine tongue and groove boards, 9 inches width, and, really, was a double box,

the boards of the inner one running at right angles to those of the outer in order to make the box as air-tight as possible. The lid of the box, which was 12 inches deep on the inside, had a 12-inch band around the edge where the lid rested on the box, and to make the joining of the two as air-tight as possible, the edge was lined with felt. Both the lid and the box were then lined with what is known as "builder's paper" or "sheathing," which secured a still better protection against outside changes of temperature. The tin box rested on a couple of wooden horses, 12 inches high, so that when placed in position, there was a space of 12 inches all around the tin to the sheathing. From the bottom of the tin box led a tube which passed into an inch pipe, this latter pipe extending through the wooden box and the lower end, being immersed in a can of water, prevented any outside air from entering either box. All fittings were air-tight. Thermometer tubes were let in from the four sides to within 6 inches of the tin box, as well as a long tube from the wooden box cover through the tin box cover to within a couple of inches of the ice.

Before starting a test the ice was allowed to melt until the drip from the can showed a regular flow, thereby allowing the true weight of ice melted during the test to be determined. During a test temperatures were noted on all four sides of the wooden box, also within 6 inches of the tin box, and also inside the latter, the readings being taken half-hourly and the weight of ice melted hourly. When the thermometer tubes were not in use, they were closed with corks. Comparison tests were made of each substance, each test lasting from six to 24 hours. As seen from the tables, tests were made of air, shavings, and cork, first at ordinary temperature and later with a steam coil an inch above the wooden box to represent the effect, when steam was circulated, of the sun on the roof of a storage house.

In the selection of non-conductors for practical service, something more than their heat-retaining power should be taken into account. They should be materials which are abundant and cheap;

clean and inodorous; light and easy of application; not liable to be compacted by jarring or to change by long keeping; not attractive to insects or mice; not liable to spontaneous combustion nor prone to attract moisture from the air, and not capable of exerting any chemical action on the surfaces with which they are in contact. There is no one thing which combines all the desirable qualities, but there are many non-conductors which embrace a considerable range of these requisites.

In the composition of this paper references have been made to articles on insulation by Prof. John M. Ordway in the *Transactions* of the American Society of Mechanical Engineers, and also by Messrs. Starr and Rassbach in *Ice and Refrigeration.*

A summary of the results by our experiments is given in Tables I., II., and III.

TABLE I.

Material cover empty, so that top of box is insulated with air. Heat applied to top of box by means of a steam coil.

Material.	Average Temperature in Degrees Fahr.		Pounds of Water Melted per Hour.	British Thermal Units per Square Foot of Surface per Hour per Degree Fahr. Difference of Temperature.	
	Room.	Material.		Outside Surface	Inside Surface
Shavings, first test...	84.13	71.187	.5	.014	.0166
Shavings, second test,	81.81	75.17	.3611	.011	.013
Cork, first test.....	89.14	81.125	.875	.0193	.0229

The results given in Tables I., II., and III. are calculated, using the external area, and using the internal area of the wooden box.

From Tables I., II., and III. it is easily seen that insulation of shavings is considerably ahead. A curious result may be noticed in Table III., where the material in second test is 4 degrees higher, and yet the ice melted nearly .2 pound less. This may be ac-

counted for by the thermometers not being left in the material long enough to get the real temperature. The shavings used were ordinary white pine, such as can be obtained from any carpenter's

TABLE II.

Cover of box full of same material as that used for insulating the sides.

No heat applied by steam coil on top of box.

Material.	Average Temperature in Degrees Fahr.		Pounds of Water Melted per Hour.	British Thermal Units per Square Foot of Surface per Hour per Degree Fahr. Difference of Temperature.	
	Room.	Material.		Outside Surface	Inside Surface
Air, first test.....	73.97	....	1.25	.044	.052
Air, second test.....	75.23	71.	1.17	.041	.0487
Shavings, first test...	77.17	66.8	.4166	.0136	.016
Shavings, second test,	78.28	66.42	.375	.0119	.014
Cork, first test.....	85.12	73.73	.802	.0223	.0265
Cork, second test.....	78.99	70.55	.557	.0175	.0206

TABLE III.

Cover of same material as that used for insulating the sides.

Heat applied to top of box by means of a steam coil.

Material.	Average Temperature in Degrees Fahr.		Pounds of Water Melted per Hour.	British Thermal Units per Square Foot of Surface per Hour per Degree Fahr. Difference of Temperature.	
	Room.	Material.		Outside Surface	Inside Surface
Shavings, first test...	79.81	65.	.297	.009	.0107
Shavings, second test,	79.2	66.2	.354	.011	.013
Cork, first test	85.12	69.42	.510	.0142	.0168

shop, and were not in large pieces or strings, but rather small, thin hips. Although the results of the shavings tests do not agree as osely as desired, the difference in favor of the second test may be

explained by the fact that the second test was really a continuation of the first test; the conditions at the start were much better, as the shavings had had 24 hours in which to cool down to a stationary temperature.

Tests of air, Table II., are really not "air-space" tests, but only tests in which the refrigerator was surrounded by a volume of air which could circulate in a confined air space, but which could receive no fresh supply from any source. These results agree as nearly as could be desired.

Tests of cork, column 2, seem to come just half-way between those of air and shavings, showing that cork is not such a good material (compared with the others) as is generally supposed.

The tests with the steam coil showed that the application of considerable heat over the top of the box had no appreciable effect upon the transmission of heat into the box.

TEST OF OTTO GAS ENGINES.*

BY J. V. MACDONALD, '93, B. G. BRAINE, '93, C. H. MERRITT, JR., '93.

THE engines tested operated part of an electric plant at Danbury, Conn., under the management of the Danbury and Bethel Gas and Electric Light Company.†

The object of the test was to determine the economy of an Otto gas engine, operated by producer gas.

The test consisted in five eight-hour runs with the working load, a Prony brake test, and special tests for the friction of the engines.

*Abstract of graduation thesis covering engine tests only, whereas electrical tests were also included in the original.

†A description of this plant with comprehensive illustrations appeared in *Power*, August, 1894.

At the same time the cupola was tested and electrical readings were taken for the purpose of determining the electrical horse-power.

An average of the five tests shows that 1.82 pounds of coal was consumed per hour per indicated horse-power, and 3.66 pounds per hour per effective horse-power.

A description of the plant follows, together with the results of tests in detail.

DESCRIPTION OF THE PLANT.

The cupola which is used for making the "producer gas" is a vertical one, similar to the one used in making part of the water gas; but specially designed for the producer gas. It has an inside diameter of 5 feet, and an inside depth of 10 feet.

The process of making the gas is that of sucking air with a small percentage of steam through incandescent coal by means of a jet exhauster, and forcing it, by means of the same exhauster, through the scrubbers, where it is washed to rid it of its mechanical impurities, into the holder, the pressure of which is about 3.2 inches of water.

From the holder it passes to the engines as required, and is there mixed with the necessary amount of air for complete combustion. A bag is placed in the gas connection to the engine for the purpose of equalizing the flow of the gas.

There are three gas engines in the plant, any two of which are used to operate the plant, the other being held as a reserve. The difficulty of starting gas engines is overcome in this plant by using a small Westinghouse 15 horse-power engine which is connected to the countershafting.

This shafting is fitted with a very heavy flywheel; and, when it has gotten up to normal speed, by a special belt shifting and tightening device, the engines are thrown into engagement with the shaft and started by the momentum of the flywheel. This arrangement is such as to cause very little slipping of the belts.

The engines are nominally rated 100 horse-power each, and consist of two single-acting cylinders arranged one above the other; compression taking place in one while the other exhausts, and

expansion in one while the other draws in its new charge of gas and air. The ignition is made by means of movable electrodes interrupting a current from six Edison Llanda type G batteries, each engine having a separate set.

The ignition occurs in each cylinder every double revolution. The governing is done by means of a cam which opens the admission valve for the gas whenever an impulse is called for.

The proportion of air to gas is regulated by a metal plate which adjusts the size of the openings of the gas and air passages; the gas and air mixing inside the cylinder.

Each engine was supplied with a revolution counter and an impulse counter, and two Tabor and two Crosby indicators were used.

The water that passed through the water jackets was measured by a Worthington Crown meter and the temperature was taken before and after passing through the jackets. The temperature of the exhaust gases was taken by means of a pyrometer.

The large quantity of waste oil from the engines is collected, filtered, and then pumped up into a tank, from which it was distributed to the different bearings by gravity.

Each engine is supplied with a balance wheel, and the countershafting also has a very heavy flywheel, which weighs 6,600 pounds and runs at 500 revolutions per minute.

Cylinder.	Diameter.	Stroke.	Clearance.
No. 2 Engine, upper cylinder.....	14.63 inches.	2.102	....
No. 2 " lower "	" "	2.092	. .
No. 3 " upper "	" "	2.099	29.76 per cent.
No. 3 " lower "	" "	2.094	29.48 " "

The power obtained from the engines is exclusively used for running the dynamos. There is a Westinghouse constant-potential alternate-current machine which supplies current for the incandescent lights about the city. This machine has an exciter for its field magnets. There is also a Schuyler continuous-current machine furnishing current for the commercial arc lights.

The results of tests are given in Tables I. and II.

TABLE I.—*Tests With Engines Running Under Ordinary Working Load.*

Number of test	1		2		3		4		5	
Date	December 27, '92.		December 28, '92.		December 29, '92.		December 30, '92.		December 31, '92.	
Number of engine	2	3	2	3	2	3	2	3	2	3
Duration in hours	7	8	7	8	8	7	8	7	8	7⅔
Total number of revolutions	69,159	73,375	69,286	74,698	78,641	69,595	77,924	07,396	78,521	75,261
Revolutions per minute	163	163	164	164	164	164	162	162	163	163
Total number of impulses	53,961	48,665	47,525	53,470	56,469	46,840	57,887	47,518	53,143	62,127
Impulses per minute	128	101	113	112	118	109	120	113	111	138
Corrected average, mean effective pressure	45.2	48.45	48.5	49.8	51.1	52.3	49.7	54.3	53.29	52.7
Average indicated horse-power	67.6	53.4	58.4	58.8	64.37	61.55	61.57	65.3	62.67	76.43
Average effective horse-power	68.65		64.87		73.57		74.52		89.35	
Gas in cubic feet used	74,253		64,917		81,231		79,507		94,493	
Gas in cubic feet per indicated horse-power per hour	82.52		73.84		85.88		83.72		84.92	
Gas in cubic feet per effective horse-power per hour	145.58		132.75		147.45		143.32		135.68	
Cubic feet of water through water jackets	1,574.90		1,436 89		1,248.82		1,099.31		1,625.36	
Cubic feet of water per indicated horse-power per hour	1.75		1.63		1.32		.16		1.46	
Temperature of water in degrees Fahr., entering	41.5	41.5	40	40	40	40	39 9	39.9	40.2	40.2
Temperature of water in degrees Fahr., leaving	83.8	98.9	86.	100.	104.	96.5	114.5	117.6	100.8	91.9
Coal in pounds per hour	123.04	97.2	106.30	107.01	117.16	112 03	111.7	118.86	114.07	139.12
Coal in pounds per indicated horse-power per hour	1.820*		....		....		....		....	
Coal in pounds per effective horse-power per hour	3.6557*		....		....		..		...	

TABLE II.—*Results of Tests With Prony Brake.*

	Without Lead.	With Countershaft.		Without Lead.				
Number of test	6	7	8	9	10	11	12	13
Date	Dec. 30, '92	Dec. 30, '92	Jan. 3, '93	Mar. 14, '93	Mar. 13, '93	Mar. 13, '93	Mar. 14, '93	Mar. 14, '93
Number of engine	3	3	2	3	3	3	3	3
Duration, in hours	1.46½	2.15	1.35	1	2	2	1	1
Total number of revolutions	17,892	12,300	15,691	10,189	19,986	19,755	9,781	9,760
Revolutions per minute	168	164	165	170	166	165	163	163
Total number of impulses	4,666	9,531	6,919	2,368	10,129	14,067	8,322	9,361
Impulses per minute	44	71	73	39	85	117	139	156
Corrected average mean effective pressure	51.1	51.5	54.53	58.6	57.0	54.8	54.21	54.83
Indicated horse-power	23.8	38.7	43.25	24.5	51.04	68.74	80.36	91.3
Effective weight on brake-arm in pounds	....	....	....	....	138.4	238.4	338.4	394.4
Brake horse-power	....	...	...	....	26.29	44.82	63.01	73.29
Horse-power lost by friction of engine	23.8	23.8	28.35	24.5	24.71	23.92	17.34	18.05
Gas in cubic feet used	5,215	8,440	6,925	2,705	10,430	13,440	7,585	9,100
Gas per indicated horse-power per hour in cubic feet	123.45	96.93	101.13	110.41	102.18	97.76	94.39	99.66
Gas per brake horse-power per hour in cubic feet	....	....	....	....	198.37	149.94	120.38	124.16

ANALYSIS OF PRODUCER GAS.

Per Cent. Composition of Gas Used on December 28.

	Per Cent. Volume.	Densities.	Weight.	Per Cent. by Weight.
CO_2	.107	1.524	.1631	.1867
C_2H_6 (Ill)	.006	.978	.0059	.0068
O	.002	1.1056	.0022	.0025
CO	.169	.973	.1644	.1882
H	.172	.069	.0119	.0136
CH_4	.006	.559	.0033	.0038
N	.538	.972	.5229	.5984
	1.000 ×	.8737 =	.8737	1.0000

Per Cent. Composition of Gas Used on December 29.

	Per Cent. Volume.	Densities.	Weight.	Per Cent. by Weight.
CO_2	.106	1.524	.1615	.1845
C_2H_6 (Ill.)	.002	.978	.0020	.0023
O	.003	1.1056	.0033	.0038
CO	.173	.973	.1683	.1924
H	.171	.069	.0118	.0135
CH_4	.004	.559	.0022	.0025
N	.541	.972	.5259	.6010
	1.000 ×	.8750 =	.8750	1.0000

Per Cent. Composition of the Gas Used on December 30.

	Per Cent. Volume.	Densities.	Weight.	Per Cent. by Weight.
CO_2	.104	1.524	.1585	.1802
C_2H_6 (Ill.)	.005	.978	.0049	.0056
O	.005	1.1056	.0055	.00625
CO	.178	.973	.1732	.1969
H	.165	.069	.0114	.0130
CH_4	.004	.559	.0022	.0025
N	.539	.972	.5239	.59555
	1.000 ×	.8796 =	.8796	1.00000

Per Cent. Composition of Gas Used on December 31.

	Per Cent. Volume.	Densities.	Weight.	Per Cent. by Weight.
CO_2	.111	1.524	.1692	.1923
C_3H_6 (Ill.)	.003	.978	.0029	.0033
O	.002	1.1056	.0022	.0025
CO	.178	.973	.1732	.1968
H	.168	.069	.0117	.0132
CH_4	.002	.559	.0011	.0012
N	.535	.972	.5200	.5907
	1.000 ×	.8803 =	.8803	1.0000

The above analyses were made by Mr. H. H. Ederton, of the Danbury and Bethel Gas and Electric Light Company. The gas for each day's analyses was taken from the large holder, at a uniform rate during the run, and collected in a small holder, so as to get an average sample.

The illuminants were taken to consist entirely of C_3H_6. The column headed "densities" means the densities of the various constituents taking air as unity. These values were obtained from a report made by Professor Jacobus on "Water Gas as a Steam Boiler Fuel."

For every pound of gas made there was .12 pound of steam drawn in.

HEATING POWERS OF THE GAS.

The results are expressed in British thermal units per pound of the gas completely combusted. The British thermal units of the various constituents are the values given in the report of Professor Jacobus previously referred to:

Gas Used on December 28.

	British Thermal Units per Pound.		Per Cent. by Weight.	
C_3H_6	20,135	×	.0068 =	136.9
CO	4,390	×	.1882 =	827.3
H	51,804	×	.0136 =	704.5
CH_4	21,593	×	.0038 =	83.0
Total British thermal units in one pound of the gas				1,751.7

Gas Used on December 29.

	British Thermal Units per Pound.		Per Cent. by Weight.		
C_2H_6	20,135	×	.0023	—	46.3
CO	4,390	×	.1924	—	845.7
H	51,804	×	.0135	—	699.3
CH_4	21,593	×	.0025	—	53.9
Total British thermal units in one pound of the gas					1,642.2

Gas Used on December 30.

	British Thermal Units per Pound.		Per Cent. by Weight.		
C_2H_6	20,135	×	.0056	—	112.76
CO	4,396	×	.1969	—	865.57
H	51,804	×	.0130	—	673.45
CH_4	21,593	×	.0025	—	53.98
Total British thermal units in one pound of the gas					1,705.66

Gas Used on December 31.

	British Thermal Units per Pound.		Per Cent. by Weight.		
C_2H_6	20,135	×	.0033	—	66.45
CO	4,396	×	.1968	—	865.13
H	51,804	×	.0132	—	683.81
CH_4	21,593	×	.0012	—	25.91
Total British thermal units in one pound of the gas					1,641.30

The air necessary for complete combustion in pounds per pound of gas is .9975 for December 28, .8942 pound for December 29, .9471 pound for December 30, .9016 pound for December 31.

The composition of the mixture in the cylinder after explosion will be:

	December 28.	December 29.	December 30.	December 31.
CO_2	.256	.261	.262	.268
H_2O	.069	.068	.066	.065
N	.675	.671	.672	.667

FINDING Y BY MEANS OF THE SPECIFIC HEATS.

	For December 28.	For December 29.
C_p CO_2	.2169 × .256 = .0561	.2169 × .261 = .0566
C_p H_2O	.4805 × .069 = .0331	.4805 × .068 = .0326
C_p N	.2438 × .675 = .1643	.2438 × .671 = .1635
C_p	.2537	.2527
C_v CO_2	.172 × .256 = .0440	.172 × .261 = .0448
C_v H_2O	.3694 × .069 = .0254	.3694 × .068 = .0251
C_v N	.1727 × .675 = .1165	.1727 × .671 = .1158
C_v	.1859	.1857

$$Y = \frac{C = .2537}{\frac{P}{C_v} = .1859} = 1.36 \text{ for December 28.}$$

$$Y = \frac{C_p}{C_v} = \frac{.2527}{.1867} = 1.36 \text{ for December 29.}$$

THE INDICATOR DIAGRAM.

The two indicator diagrams shown are actual cards, and are good specimens of the cards taken during the test; Fig. 1 representing the ordinary card (120-pound spring), with its ordinates doubled, and Fig. 2 a compression card (20-pound spring), for the purpose of obtaining more accurately the negative work.

To describe the circle we will start at *a*, the cylinder being filled with the charge of gas and air. It is now compressed as shown by the line *a b c*.

The explosion begins at *c*, and its effect extends to *d*, and then expansion takes place from *d* to *e*, at which latter point the release is opened, and the burned gases escape, being forced out as represented by the line *f h*, and finally a new charge is drawn in as represented from *h* to *a*.

If the engine does not call for a new charge, which is regulated by a governor, air is merely drawn in and compressed and then

expanded again along the compression line or a little above it, the air having been heated by the hot walls of the cylinder.

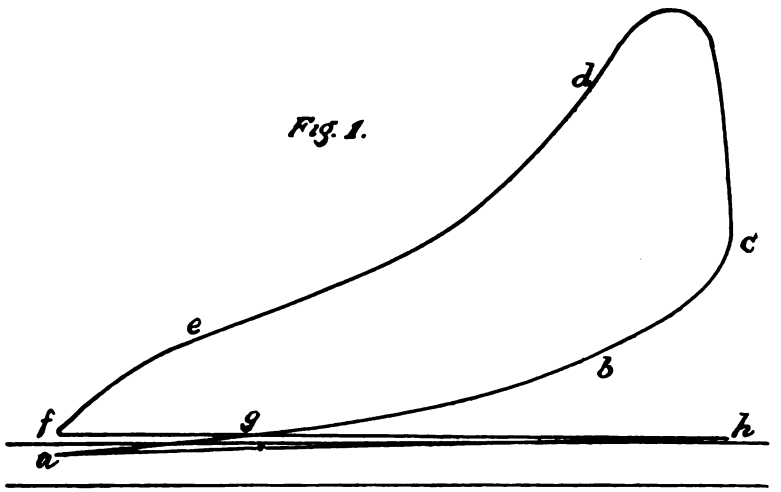


Fig. 1.

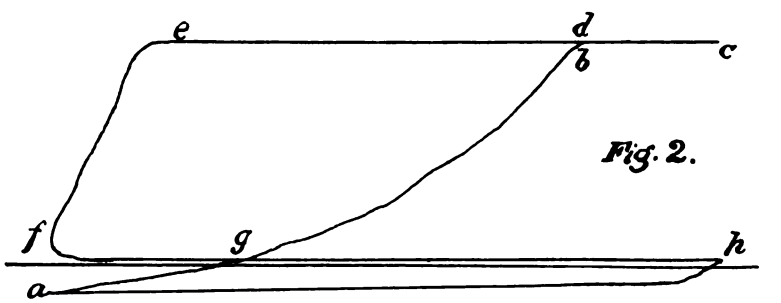


Fig. 2.

RELATION BETWEEN PRESSURES AND TEMPERATURES.

Considering the expansion to be that of a perfect gas, we have the following deductions:

$$R = C_p - C_v = 778\,(c_p - c_v)$$
$$= 778\,(.2527 - .1856) = 52.126,$$
$$pv = RT = 52.126\,T.$$

The temperature of exhaust will be T_e.

$$T_e = \frac{p_e v_e}{R} = \frac{7{,}722 \times 7.79}{52.126} = 1{,}173, \text{ or } 713^\circ \text{ Fahr.},$$

but it was found by a pyrometer to be 680 degrees, a difference of 33 degrees.

The temperature at the beginning of expansion T_d is found similarly:

$$T_d = \frac{p_d v_d}{R} = \frac{20{,}520 \times 3.584}{52.126} = 1{,}410, \text{ or } 950^\circ \text{ Fahr.},$$

and at the point where the pressure is greatest it is 865° Fahr.

The highest temperature is found to be midway between the last two points worked out and is 986° Fahr.

If the gas expanded to atmospheric pressure at 60° Fahr., then the final volume would be:

$$v = \frac{RT}{p} = \frac{52{,}126 \times 520}{2{,}116.8} = 12.8 \text{ cubic feet},$$

or more than half as large again as the volume of the cylinder.

T is absolute temperature.

EQUATIONS OF LINES.

Assuming the expansion and compression lines to be adiabatic, we have the general expression $p_o v_o^n = pv^n$ in which we have to determine n.

For the expansion we have:

$$p_d v_d^n = p_e v_e^n$$

$$\log. p_d + n \log. v_d = \log. p_e + n \log. v_e,$$

whence

$$n = \frac{\log. p_d - \log. p_e}{\log. v_e - \log. v_d}.$$

$$n = \frac{\log. 152.5 - \log. 53.625}{\log. 7.79 - \log. 3.584} = \frac{2.1832698 - 1.7293673}{.8915375 - .3371695}$$

$$n = 1.346.$$

For the compression

$$n = \frac{\log. 45 - \log. 16.248}{\log. 7.79 - \log. 3.584} = \frac{1.6532125 - 1.2107999}{.8915375 - .3371695} = 1.312.$$

1.36 having been found or n from the relation of the specific heat at constant pressure and at constant volume.

THE DISPOSITION OF THE HEAT.

In a gas engine the heat is disposed of in four ways—namely, indicated work, that lost in exhaust gases, that lost in the water jacket, and that lost by radiation.

The indicated work is found to be 19,756 foot-pounds for a single cycle.

The foot-pounds of energy lost by the exhaust gases is found as follows:

British thermal units $= .2523\ (T_1 - T_0) + 966\ w + (T_1 - 212)\ .48\ w$ (for one pound of gas).

British thermal units $= .071\ [.2523\ (680° - 60°)] + 966 \times .008307 + .008307 \times .48\ (680 - 212)$.

British thermal units = 21, or 16,338 foot-pounds.

In the above equations:

Weight gas used in cycle = .071 pound.
Specific heat of the gas = .2523.
Weight of steam in the gas = .008307 pound.
Temperature of exhaust = 680° Fahr.
Specific heat of steam = .48.

The heat lost in the water jacket, reduced to foot-pounds, was found to be 42,869 foot-pounds, leaving 15,246 foot-pounds as that lost by radiation, the total heat of the gas being 94,217 foot-pounds.

Expressed in per cent. we have:

		Per Cent.
19,756	foot-pounds indicated heat	21.0
16,338	" " heat lost by exhaust	17.3
15,246	" " " " " radiation	16.2
42,869	" " " " " water jacket	45.5
94,217	" " total heat of gas	100.0

EFFICIENCY.

The efficiency as rated from the indicated heat is 36 per cent., but as the indicated heat is only 57 per cent. of that in the gas, it is evident that it should be rated from the heat of the gas; and, thus rated, is 21 per cent.

It was found that for the entire test we obtained one indicated horse-power per 1.8 pounds of coal. Now, if we take 14,000 British thermal units as the heating power of the coal, we obtain 10.1 per cent. efficiency as the efficiency of the cupola and engines together.

It was also found that for the entire test one pound of coal made 40.0 cubic feet of gas.

DESCRIPTION OF BRAKE.

For the Prony brake test there was an extra flywheel attached to the spokes of the engine flywheel, and it was kept cool by means of a small stream of water running on the inside of the rim.

On this was placed the Prony brake, which consisted of a lever arm 84.2 inches long, weighing 73 pounds, resting on an edge on a platform scale 72 inches from the center of the wheel. This lever arm was braced by means of an arm 41½ inches long weighing 27¾ pounds.

There were also 10 pounds on the scale in the form of a block and knife edge.

The weight on the scale was kept constant, and the brake tightened or loosened to make the scale balance.

The speed was fairly constant during the test, becoming, however, more irregular with the heavier loads.

We are indebted to Anson W. Burchard, M. E., for his kind assistance in conducting the test, and also to the Danbury and Bethel Gas and Electric Light Company for the privilege of making the same, and for many favors which they and the superintendents and employees so willingly extended to us.

ALEXANDER C. HUMPHREYS.*

THE retirement of Mr. A. C. Humphreys from the position in which the gas fraternity has grown into knowledge of him, as engineer and man, needs more than passing notice. It is not the ordinary retirement of a well-known official from active business cares, but rather the laying down of a life-work, for into the 10 years which Mr. Humphreys has spent in the service of his company he has compressed more hard work and energy than the average engineer would expend in his generation, and the result of this is shown in the system which he leaves behind him, complete, with every thread in exact place in the network, a proud masterpiece of executive skill, and the use of brains in management. If Mr. Humphreys' active life were to end to-day, he could be justly proud of the record he has made; but years and paths lie before him, and from the past we are justified in gauging the future. Mr. Humphreys has work before him which will test his abilities and develop his strength in lines other than those in which he has so long held leadership.

An impartial history of the progress of water gas during the past 20 years must place in the foremost rank three names. These are Lowe, Granger, and Humphreys. To the first belongs the palm of mechanical success; to the second, that of commercial success; to the third, that of the perfect development of both of these. If such a history were to be confined to a single chapter, the caption of that chapter might well be written: "Water Gas, Before and After Humphreys." The development of the Lowe, from the state of possibilities into that of achievements, which has been wrought through his work, merits such distinction to the worker, and no

*"Light, Heat, and Power," May, 1894.

engineer, with even a general knowledge of what has been accomplished in bringing the manufacture of water gas to the status of to-day, would question the justice of such a caption. The minutiæ of the processes by which this result has been accomplished are best understood by those who are left to continue the work; the general scope is known to all; and in this knowledge we make judgment.

In the accompanying sketch will be found the simple statement of how this work was accomplished, and of some of the difficulties under which the worker labored. While this sketch will be of general interest in giving more than has before been given of a career in which the gas men of this country justly take pride, its chief value will lie in the lesson it holds for the new beginner, who is timidly treading the path which Mr. Humphreys has shown can lead to brilliant success. This lesson is twofold. In the first place, it shows that engineering studies can be successfully pursued and without loss of time under the pressure of everyday work and all the vicissitudes that beset the life of a gas works superintendent. In the second place, it teaches the benefit of a grounding in practical work, either commercially or otherwise, as a basis for the building of a successful engineering career. Perhaps this latter lesson is one that needs appreciation, not only by the beginner, but by the older ones among us who are too apt to disregard the value of such a combination.

It is a satisfaction to Mr. Humphreys' friends to know that his health, which was severely threatened a few years ago, has been completely restored, and that he steps from his old life into the new with the full vigor of physical and intellectual manhood. In this new life he will have the well-wishes of all honest gas men.

ALEXANDER CROMBIE HUMPHREYS was born in Edinburg, Scotland, March 30, 1851, of English and Canadian parentage. With his parents he came to this country in the fall of 1859, the family residing in Boston, where young Humphreys attended school until

the fall of 1864, when he was between 13 and 14 years of age. Previous to this time, he had obtained an appointment to the United States Naval Academy, and had passed a test examination for entrance, but when it was ascertained that he was less than 16 years of age, he was not permitted to enter. He left school and began a business life, ostensibly waiting for the necessary time to elapse before he could be admitted to the Academy. But, eventually, he drifted away from the idea of entering the naval service.

This first entrance into business life was in an insurance office in Boston. Shortly after, the company becoming financially embarrassed, young Humphreys, finding himself out of a situation, went to New York City, where, in the fall of 1866, he obtained a position as junior clerk in the New York Guarantee and Indemnity Company. With this company he remained until the spring of 1872, having in the meanwhile risen to be receiving teller and assistant general bookkeeper.

For a year previous to this latter date, Mr. Humphreys had been acting as Secretary to the Building Committee of the Bayonne and Greenville Gas Light Company, of Bayonne, N. J., a company which had just been organized to supply gas to Bayonne City. Upon the completion of the works, he was asked to become secretary of the company and to take charge of its business interests. For a long time he had felt strong inclination toward things practical, in spite of no direct family influences in that direction, his father being a fine classical scholar and devoted to classical pursuits, and he had developed a strong tendency toward the use of tools and appliances, in which, however, he found but little time or opportunity for practice. The offer of the Bayonne company, presenting to some extent such an opportunity, was accepted, and accordingly just 22 years ago, at the age of 21, Mr. Humphreys entered the gas business as a practical factor. At the end of the first year of business, the Bayonne and Greenville Company decided to reduce expenses, and Mr. Humphreys was asked to assume full charge of the works as Secretary and Superintendent. It was, therefore, in this

little works and with this little company that the educational work that has given Mr. Humphreys his present standing began.

In the spring of 1872 Mr. Humphreys had married Eva, daughter of the late Dr. Emile Guillaudeu. They have two children, a daughter, born in 1873, and a son, born in the fall of the first year in Stevens, 1877.

Gradually becoming convinced that something more than an ordinary liberal education was needed to insure genuine progress in his now chosen work, Mr. Humphreys consulted Dr. Henry Morton, President of the Stevens Institute of Technology, who told him that, with a man of determination, it would not be impossible to go through the entire course of Stevens without relinquishing his position with the gas company, although he thought that it would most probably require six years for the completion of the full four years' course. The directors of the gas company readily granted permission for an absence of two mornings in each week, thus enabling their Superintendent to attend the most necessary lectures at Stevens, and to keep track of the regular work of classses. Mr. Humphreys threw himself into this work, attended in full all reviews and examinations, doing the greater part of his collegiate work at night, and being substantially aided, so far as his routine of gas duties was concerned, by Mr. C. J. R. Humphreys, who had by this time gotten well into the gas harness. Entering Stevens in the fall of 1877, the Superintendent-student surpassed the expectations of Dr. Morton in graduating in 1881, consuming only the regular four years' course, although, in so doing, he found for the first time that he had nerves.

In a recent letter, Dr. Morton refers to the unusual progress made by Mr. Humphreys, and quotes from the minutes of the Faculty of Stevens, under date of June 11, 1881, the following resolution presented by Professors Wood and Mayer:

Whereas, Mr. Humphreys, who now graduates, has been occupied as an officer of a gas company in a neighboring city, and also as an officer in the School Board; and

Whereas, he has in addition to his outside labors completed our course with honor and earned a high standing in his class; therefore

Resolved, That we express to him our appreciation of his efforts and our satisfaction at his success.

Dr. Morton also notes the fact that "on December 23, 1891, the Board of Trustees of the Institute, which had consisted since its origin in 1870 of only three members, was increased by the election of Mr. Humphreys, in company with Messrs. Andrew Carnegie, Charles MacDonald, E. N. Stevens, and Chancellor A. T. McGill." This election constitutes a life membership of the Board.

Mr. Humphreys served one term as President of the Stevens Alumni Association, and at the Commencement of last year delivered the Address to the Graduating Class.

Mr. Robert M. Dixon, Manager of the Pintsch Company, writes of his old classmate: "I first knew him in 1877, when he entered the Freshman Class of Stevens; and throughout the course he stood head and shoulders above any other member of the class."

In the meantime, and while going through Stevens, Mr. Humphreys had become strongly identified with local interests. For several years he was Superintendent of the Sunday School of Trinity Episcopal Church, member of the vestry and Treasurer of the same church. For four years he was a member of the Bayonne Board of Education, and for a portion of his residence in Bayonne, Foreman of the Volunteer Fire Company, besides serving other lesser local interests.

In the fall of 1881 he accepted the position of Chief Engineer of the Pintsch Lighting Company, in which position he remained for about 3½ years, finally resigning because those who were controlling the company were not willing to work along the liberal lines necessary to the proper development of business. While in this position Mr. Humphreys built many small gas works and obtained considerable experience in railroad car equipment, etc.

During this time he also conducted much experimental work. On leaving the Pintsch Company he was offered a number of propositions, finally accepting the position of Superintendent of Construction of the United Gas Improvement Company, joining that company January 2, 1885. A few months later he was made General Superintendent. In this position Mr. Humphreys has built up the present system of management of controlled companies that is the admiration of gas men throughout the world, and which enables the company's small army of employees to be worked as a unit. In 1885 the company had practically no well-defined system for managing its various properties, which at that time numbered less than 10. During the next one or two years, while the new system was being developed, more than 20 works were added to the above number.

The development of the Humphreys system, which is the chief distinguishing work of its author, had to be undertaken without any guide in the way of previous experience, and nothing to copy after. Those who have known Mr. Humphreys for the past 10 years know what a severe strain the first four or five years of this work was upon him. Working literally night and day, with about half his time spent in this city, and the other half in visiting the various stations of the company, with the labor of uniting so many different elements and different methods into a consistent working whole, there was little, if any, time for rest. Almost at once, upon taking charge as General Superintendent, Mr. Humphreys, bearing in mind his own early difficulties, laid down the plan of building up a corps of technically educated assistants. This added severely to the strain of these early years, as the young men chosen were graduates from Stevens and other colleges, necessarily inexperienced in practical work, who were put through a regular course of training as gas engineers and managers. While this course of procedure made more work for its originator at the start, it finally resulted in the development of the present corps distinguished for its efficiency.

When Mr. A. O. Granger severed his connection with the United Gas Improvement Company, the department for sales of water gas apparatus was given into charge of Mr. Humphreys, and about the same time he was also given charge of the commercial branch of operating department, including the purchasing department. Those who know something of the detailed work necessary in the proper manipulation of one good-sized gas company, will be able to appreciate from the foregoing the amount of work which Mr. Humphreys has carried, and carried successfully, during his nearly 10 years of service with his present company. His greatest success, however, has been in bringing the system he inaugurated to its present state of perfection, where the force in charge is well qualified to carry on its necessary work without his leadership, and, consequently, he is enabled to feel that, in obeying his personal wishes, he is not subjecting the affairs of his company to any embarrassment. His resignation, tendered in April, will take effect in August next, within five months of a rounded 10 years' service.

The following resolutions were unanimously adopted at the sixth annual meeting of superintendents of the United Gas Improvement Company, Philadelphia, April 21, 1894:

Whereas, Alexander C. Humphreys, General Superintendent of the United Gas Improvement Company, has, at this meeting of superintendents, engineers, and other employees assembled, announced his resignation and withdrawal from the service of the company; and

Whereas, This announcement is received by us with profound and heartfelt regret, it is herewith

Resolved, That this occasion be taken to express to Mr. Humphreys our deep regret at the severance of the present relations; that we herewith convey to him the expression of our admiration, esteem, and affection for him as a man; and that we extend to him our heartfelt wishes for his success in whatever lines of work he may hereafter engage.

To the building up of a business to be carried out on lines that were a departure from existing precedents, there was required a

man of unusual foresight, ability, and clearness of purpose. In the development of the United Gas Improvement Company, under Mr. Humphreys, we recognize the logical outcome of such ability and the work of a natural leader and of a manager foremost in his profession, and we believe that the working organization that he has perfected stands to-day the best and most enduring monument to his labors.

A conscientious worker, rarely skilled in his profession, indefatigable, and earnest in purpose, he, more largely than has any other one person, has been the factor that has brought the United Gas Improvement Company to its present enviable position in the gas world; to a point wherein its integrity, rank, and purpose is recognized, and where connection with it is an honor to every man of us here assembled.

But while we recognize, as above, the business ability of Mr. Humphreys, there is yet a deeper and a sweeter attraction that draws us all to him, and that makes the pain of losing him the greater, and that is his integrity, his individuality, his personality, and his magnetism as a man. Rarely, indeed, is seen a man so conscientious in his effort to meet his responsibility to his employers; so keenly appreciative of earnest work; so impartial in his judgment; so constant and so successful in the effort to act with fairness to all. Of no man can it more truly be said, "He is a man of honor, integrity, and justice."

To the younger men of us his example is one for admiration and inspiration, showing the possibilities of a man. To the older men here assembled who have known him during years of association and of ever-increasing respect, there is but admiration at his unswerving adherence to his principles and belief, for his constant kindliness, his daily living of the Golden Rule. In his new fields of labor the united good wishes of this assembly go out to him for his success, joined with the earnest hope for continuance to him of good health.

Again, in losing him we express the unanimous, profound, and heartfelt regret of every man among us, for in working with him we have learned to love him. It is further

Resolved, That a suitable and permanent copy of this preamble and resolution be prepared and transmitted to Mr. Humphreys in commemoration of this occasion.

J. H. KEPPELMAN, *Chairman.*

In seconding the adoption of these resolutions Mr. S. T. Bodine, General Manager of the United Gas Improvement Company, spoke as follows: "My lips are often dumbest when my heart speaks loudest. No one knows this better than my very dear friend, Alexander C. Humphreys. The beautiful and touching words in which your committee have expressed our feelings, and in which those who have spoken have emphasized those expressions, need no addition from me; but I must add my personal tribute. I am satisfied that no one man has done so much to place the United Gas Improvement Company where it stands to-day as Mr. Alexander C. Humphreys. By training, by natural aptitude, he has been peculiarly fitted to combine the commercial and engineering management of our business, and this very fact has brought him into closer touch with every man in the service than it has been the privilege of any other man to be brought. Certainly the greatest element of success in this life is character; to build up a true character in ourselves and help our fellow men to build up their characters. They say that corporations have no souls, but I don't believe it. The soul of a corporation is the composite soul of those who represent it; and certainly no corporation in this broad land has a nobler, broader soul than is represented in the characters of the men that Mr. Humphreys has drawn together around him in the management of this business. He has not been satisfied with impressing his influence on you, and learning to know each one of you individually, but he has worked away on what he has often found to be very rocky soil, on the hearts of the President and General Manager, so that we have come to know you, not by the cold figures of the chart, but as individual men—each one with his own particular capacity and his own particular strong and weak points. Beside the element of character there must be the element of life. Mr. Humphreys has selected in days gone by, as assistants in the development of the business, two good and true men, worthy in every respect to take up the mantle that he lays down—Walton Clark, as General Superintendent, in charge of the engineering

department, and Lewis Lillie, as Comptroller, in charge of the commercial department.

"Mr. Humphreys, in the trials and rebuffs and disappointments that are to befall you, as befall all of us they must, you will have no truer sympathizers than we. We know how bravely you will bear them. In the great successes that we hope and believe are in store for you, there will be no heartier plaudits than those which come from your old friends who rally under the banner of the United Gas Improvement Company. We can pay you no greater compliment, I know, than to promise you that we will not rest satisfied with the standard you have established, but will do our utmost to elevate it."

During the year 1890, Mr. Humphreys visited Europe in the interests of the United Gas Improvement Company. Shortly after his return, the Gas Light and Coke Company, of London, contracted with the United Gas Improvement Company for a water gas plant for its Beckton works. Mr. A. G. Glasgow, General Inspector, was sent over to erect this plant. Some time later, Mr. Glasgow left the company, finally returning to England, Mr. Humphreys later joining forces with him, and the firm of Humphreys & Glasgow was established. This firm began its career by the erection of a double plant in Copenhagen. Since then, plants have been erected, or are in course of construction, for Glasgow, Belfast, Brussels, Liverpool, and Tottenham. Following the course originated in the case of the United Gas Improvement Company, Messrs. Humphreys & Glasgow have gathered around them a group of well-educated, well-balanced, common-sensed engineers, and the force is described by a prominent British gas manager as being already a most efficient one.

He has contributed several substantial papers to the gas literature of the country, the principal of these being "Water Gas in the United States," which was presented before the British Association for the Advancement of Science, at the request of the President of its Mechanical Section, in 1889, and afterwards republished in book form.

The system of lighting schedules, prepared by him, has for several years been acknowledged as standard, and at the present time it is probable that three-fourths of the gas and electric lighting companies of the country follow the hours set in the Humphreys schedules.

COMMENCEMENT WEEK.

CLEAR skies and typical June weather, to which July had, however, advanced liberally of her heat, favored the Class of '94 and the alumni and friends of Stevens who had the opportunity of participating in the events of Commencement Week.

Rev. William R. Jenvey, pastor of St. Paul's Protestant Episcopal Church, Hoboken, delivered the Baccalaureate Sermon at 10 A. M., Sunday, June 17, taking for his text, 1 Kings xii. 28.

Monday was Class Day, and the exercises began at 3 P. M. with the planting of an ivy near the window of President Morton's office. Mr. Rosenbusch, on behalf of his class, made the presentation speech, closing with the modest hope: "May we in our profession and the ivy in its growth keep pace with each other, so that when we return as proud sons of Stevens we shall see her walls covered with the clinging vine *our* class has planted."

President Morton, in the name of the Institute, accepted the ivy and said:

"This ivy which you have planted will furnish an agreeable and appropriate memorial and reminder of the Class of '94.

"When I look at it in the bright days of spring and summer it will recall the verdant freshness which from time to time has delighted all of your instructors, and when amid the storms of winter I see it firmly holding to its place and successfully resisting the onslaughts of the wind and rain, I shall think of the many successful struggles in which you have overcome the difficulties of your road to Parnassus. As when you forced your way through the mathematical hedge, Bristoling though it was with difficulties, and tangled with cunningly-spun Webbs of analytical mechanics, and when you traversed the dark and dangerous Wood infested with Thermodynamics, Indicators, Valve Gears, and like designing monsters of Engineering.

"But you have escaped all and are now safe, if not without many a wound and Dent-on your armor.

"In conclusion let me hope that this ivy may be a symbol for the future as it is a memento of the past. As in its tender youth it will owe support and training to the walls of the Institute, but in its maturity will decorate them with its leaves and branches, so may you who have received your training within these walls one day crown them with the honorable wreaths won by you in successful contests with the world and nature in your professional careers."

At the conclusion of these ceremonies the assembled company proceeded to Castle Point, whose shady and delightful lawn Mrs. Stevens had invited the class to enjoy in their Class Day exercises.

Mr. Angell bade welcome to "Our parents, our sisters, our friends, and our friends' sisters." Mr. Oppermann called the class roll, disclosing the absence of several of its members.

The class history was related by Mr. Lawton, all important events being cursorily reviewed.

Music by the Mandolin Club was then followed by the "Invocation" by Mr. Hartpence.

Gifts to the members of '94 were bestowed by Mr. MacCord, with all necessary explanations to the recipients and their acquaintances of the appropriateness of each present to its recipient.

Mr. Lozier delivered the class prophecy, a farewell song was sung by the class, and a parting yell closed the exercises.

President Morton then extended a very cordial invitation from Mrs. Stevens to all present to partake of refreshments served on the veranda.

By 8 P. M. it was evident that '96 had made exceptional preparation for the cremation of Calculus.

With costumes, decorations, fireworks, and noise unlimited, the procession served unquestioned notice on the residents of Hoboken's principal streets that High Court was about to open at Stevens Institute.

The guilty one suffered the penalty, and all who did not suffer, rejoiced.

The scene of rejoicing was quickly transferred from the Campus to the physical laboratory, where President Morton received the undergraduates.

From four to seven on Tuesday the Rho Chapter of Delta Tau Delta held a reception at the Chapter house, 1034 Bloomfield Street, which proved a highly enjoyable occasion.

The Class of '94 met for their farewell dinner at 8.30 P. M. on Tuesday, at Busch's Hotel.

On Wednesday afternoon, June 20, President and Mrs. Morton held their annual reception to the Faculty, Alumni, and Undergraduates.

Mrs. Morton was assisted by Mrs. Frank Stevens, Mrs. Richard Stevens, Mrs. McGill, Mrs. J. Bryan, Miss Duer, Miss Humphreys, and Miss Pickhardt.

The annual meeting of the Alumni Association was held the same evening.

Commencement Exercises were held on Thursday, June 21, at 8 P. M. at the Hoboken Theater. The house was well filled, the music exceptionally fine, and the programme smoothly carried out.

Rev. William R. Jenvey opened with a prayer and President Morton made appropriate introductory remarks.

Mr. Joseph G. H. Cottier delivered the following

SALUTATORY.

"*Mr. President, the Faculty, Trustees, Fellow Students, and Friends:* To-night my classmates of 1894 have the sweet but sad pleasure of bidding you welcome to the exercises which mark their farewell to old Stevens, to the dear old Stevens, that we have all learned to love and cherish in the short four years we have spent within her walls.

"The hour for which we have longed has at length arrived, and its bright anticipations are about to be realized. Once more and for the last time the walls of our beloved institution have resounded to the tread of our feet. To-night we bid you a hearty welcome to participate with us in the exercises attendant upon reaching the goal of our ambition, for which we have struggled during the past four years—the greatest of all events in the life of an undergraduate—the presentation of his diploma.

"This wonderful diploma was as a distant star to the innocent Freshman, which would give to the possessor a talisman of indeterminate power. To the wiser Sophomore that star was the guardian angel which helped him to survive the onslaught of the fearful calculus. To the Junior, it waxed and grew, and as barrier after barrier was removed, in the shape of examinations passed, he began to have some hopes of some day possessing it, until at last as Seniors, and with the last ordeal of thermodynamics over, we felt it quite within our grasp. Nor has the value of this wonderful thing diminished, as we grew nearer to its possession, else we long ago would have given up the Herculean task of seeking to obtain it.

"The Class of '94 has charged and carried the fort; the prize has been fairly won; but after the charge, as we look backward, we find the victory has cost us dear. We count our dead, our wounded, and our missing. Scarcely half of those who matriculated with us four years ago are here to-night, although new recruits have been received on the way. Some of us have sought other pursuits, some have been compelled to give up the task because of failing health.

"But there are others whose footprints ceased upon the sands of time, when ours continued, and whom, indeed, unless they are here now with that silent tread which leaves no sound upon the air, no circumstance of earthly time or place can ever restore to us. A thought of sympathy for those who should be with us to-night, but are not, can surely not be amiss now in the hour of our success, although our hearts are filled with the brightest hopes for the future.

"I have heard it said by one who knew from personal experience that when a young man started out in professional life he was thoroughly imbued with the idea that his particular function in life was to revolutionize the world, that the combined wisdom of centuries was as nothing compared to the marvelous advances to be made in art, literature, and science by the operation of his mighty intellect, and that the world had only been awaiting his advent to emerge from darkness into life. In a few years, however, the youthful illusion is dispelled, the self-confidence is gone, and he finds, often to his mortification, that there were others before him who really did know as much as he does. But, my classmates, there is another side to the picture. That same vaulting ambition, that same youthful enthusiasm, if continued, when toned by experience and maturity, is what makes the graduate of to-night a potent factor in the affairs of the world, in years to come, an honor to his Alma Mater and a worthy example to succeeding classes. To the men of '94, I trust that there will come no rude awakening in time to dispel their brilliant dreams. A wide field has suddenly opened up before us, and each man should be forgiven his bright reveries of success therein, for such are not ill-founded, if we can judge by those who have gone before us, blessed and fortified with an education at Stevens Institute.

"This night we will receive our diplomas, and to-morrow will be launched forth upon the world, to do battle for our bread, and to seek a niche in Fame's lofty temple, to woo Fortune in a world where the survival of the fittest is the law paramount. We enter upon a new career where we will be called upon to apply what little

knowledge we have acquired at the cost of so many burnings of the midnight oil.

"We may picture to ourselves the knowledge of mankind as a palace where each room is devoted to the advancement of some branch of teaching, with cross passages and corridors connecting the chambers, until a layman would be bewildered in the maze—some of the rooms still unknown, and some still resisting man's greatest efforts to effect an entrance. Through such a place we have just passed, guided through its halls by a kind Faculty; but the utmost they could do for us was to throw open the door of some chamber, that we might get a glimpse of the vast and wonderful interior, only to close again its portals, as we were hurried on to some other and still more wonderful science.

"After having been permitted to peep into those chambers that the wisdom of our preceptors deemed most important, we are now at the end of our inspection trip—practically on the threshold of our education—and, looking backward, we are soon to make our choice. Each one of us has been captivated by the plans of some of its chambers, and to-morrow will hasten to its entrance in order that he may be admitted and labor there until he shall have graven his name in flaming letters upon the indelible page of science, or until an Almighty Providence shall call him to that other and grander palace, the palace of everlasting joy.

"And now, my classmates, let us hope that when to-morrow's sun shall gild the tower of Stevens Institute, we may each go forth to our chosen duties, strengthened and purified by this sweet final communion with our past, and with nobler aspirations for the future."

The address to the graduating class was made by Mr. J. Hector Fezandié, '75, on

THE MORAL INFLUENCE OF A SCIENTIFIC EDUCATION.

"*Mr. President, Ladies and Gentlemen:* I suppose that on an occasion of this kind the speaker is expected to prepare some sort

of a dissertation on 'How to Become a Millionaire,' or 'How to Acquire Fame.' If so, President Morton's selection of a speaker in this instance has been most felicitous. I know of no one better equipped than myself to treat these subjects. There is perhaps only one other subject which I feel I could expatiate upon with equal freedom from bias or prejudice, upon which I know I could give such valuable advice, in which I should feel so much at home, so untrammeled by practical details. The subject I refer to is 'How to Catch the Sea Serpent.'

"My experience in capturing sea serpents is somewhat limited, and I have noticed that there is no factor so indispensable to the formation of a complete, positive, unfaltering opinion on any subject, as the absence of prosaic experience. For instance, there was a time when I could have written an invaluable treatise on 'How to Bring Up a Baby.' But to-day, in the light of subsequent events, I confess with humility that, in the presence of any unforeseen crisis, I should at once apply for advice on this subject to the single ladies of my acquaintance, and to my bachelor friends.

"But, gentlemen of the graduating class, I have no intention of telling you how to become wealthy or famous.

"My intention is to submit for your reflection a few remarks which will possibly partake of the nature of a sermon, but which will perhaps have one redeeming feature—they will be brief.

"I suppose every thoughtful man has been painfully impressed by the apparently widespread moral disintegration which seems, especially of late, to have attacked the commercial and financial world, to have gangrened the body politic, to have tainted our social structure. One need not be a pessimist to conclude that the existing evil is not due simply to isolated cases of moral atrophy. The disease is more deeply rooted than that; its existence and development is due to the general lack of moral tone in public opinion, for public opinion is all-powerful whether for good or for evil. Wise and virtuous legislators—let us hope the species is not

extinct—may make whatsoever laws they choose, but no law can exist outside of the statute books unless it receives the support of public opinion.

"Now, public opinion is the opinion of everyday men and women; and, if it is not always what it should be, I believe the fault can always be traced to a wrong system of education.

"My purpose this evening is to emphasize the fact that the education which you young men of the Class of '94 have just received is admirably adapted to develop a sound morality and to build up a strong character, to provide you with the elements required to enable you to successfully resist the temptations which beset the path of every human being.

"Mark Twain, in his philosophic essay on the 'Art of Lying,' has said that an injudicious lie is sometimes almost as pernicious as the truth. That many people agree with the genial philosopher is shown by the broad application which the principle embodied in this aphorism receives in our political, commercial, and social world. Many who might not perhaps accept the doctrine as thus broadly laid down, do nevertheless, by their practice, tacitly accept the amendment that an '*injudicious*' *truth* is worse than a '*judicious*' *lie*.

"The fact is, truth has never been popular Questions have generally been judged by the standards of 'my doxy' and 'your doxy.'

"But truth is the foundation stone of modern science, and a scientific training may be defined as that form of education which leads a man to seek the truth, to understand the truth, and to tell the truth.

"In the presence of Nature, it is not the place of the investigator to ask, What should be? What might be? What interpretation of the fact would redound to his interest or to his honor? But simply and humbly, What is?

"The man of science must therefore be fundamentally honest; honest toward Nature, honest toward himself, honest toward his

fellow man; and his honesty must be something broader, deeper, better than that honesty which is only a policy.

"I do not mean to assert that men of science are necessarily composed of a different clay from their brethren in other walks of life. As men, they are subject to the limitations of mankind. No individual can be absolutely free from prejudice and mental or moral bias, any more than he can be free from physical imperfection. But the whole education of the man of science is adapted not only to render his senses more acute and more reliable, but also to put him on his guard against that tendency to error which is due to his own mental obliquity of vision, to the imperfections of his moral nature.

"He alone is a true man of science who has acquired to an eminent degree that consciousness of his own fallibility which enables him to establish what the astronomers would call his personal equation, the measure of the distortion produced by his bias, by his prejudices, by his interests.

"So, too, the veritable man of science is of necessity modest. How can he be otherwise if he be conscious of himself; if he measure his mite of knowledge by the standards of the infinite unknown? Be his genius, his power, his industry what they may, what has he accomplished at the end of a well-filled existence? He has been as one of a myriad of ants, struggling with his grain of sand, and has perhaps succeeded in placing it in position. His achievement is unquestionably valuable to the community; perhaps his grain of sand may seem larger and heavier than that carried by any of the contemporaneous ants, as fine a grain of sand as that ever transported by any ant that ever lived. But his life's work is not an ant hill for all that, and an ant hill at the best is not very large as compared with a mountain, and is still smaller in comparison with the universe. While, therefore, the man of science has
ame right as his fellow ant to feel proud of his work if he has
nplished his task to the best of his ability, he will realize how
his maximum is at the best; he will be modest.

"And with humility goes toleration. The man who is fully conscious of his own liability to error must needs be patient with the errors of his neighbor. He will respect an honest conviction for its honesty if he can admire it for nothing else.

"He will loathe the sin and pity the sinner.

"These, gentlemen of the graduating class, are to my mind the chief benefits which have been offered you during your stay in this institution. If you have made the best of your opportunity this will be of even greater importance to yourselves, and to the world at large, than the machines that you may build or the discoveries which you are destined to make; for your lives will in themselves be valuable contributions to mankind, and will leave behind them their indelible impress on the future of the human race.

"And now, my friends, my sermon is at an end. But before I say Godspeed, let me whisper a word of encouragement.

"On the threshold of your careers, when, fired with the enthusiasm and ambition of youth, you are restlessly awaiting an opportunity to put your foot into the stirrup, you will often be met with the disheartening assurance, expressed or implied, that the world has not been waiting for you.

"Do not let that discourage you; and, above all, do not believe it. It is not true. The world has done nothing else so important as to wait for you, for the world knows very well that you are posterity, and that, were it not for your generation it would surely and speedily come to an end. You are the sole arbiters of its destinies, the sole heirs to its estate. All the grand achievements of the past, all the toil and suffering of untold generations, have gone to build up for you an inheritance of wealth, knowledge, and power.

"But with great power goes great responsibility. Yours it is to see to it that the succeeding generation shall in due time receive its inheritance from your hands, not merely intact but with accumulated interest.

"Then, prepare yourselves for your inheritance, and dream your dreams of eternal youth and happiness, of fame and fortune, if you

will, though these do not constitute happiness, and do not forget that dream in which the central figure is a more or less distinct vision of an angel in white or pink, with a still more shadowy vision of a couple of cherubs at her knee.

"Some dreams are destined to be realized; most, possibly are not. But the true happiness is perhaps in the dream itself, for the dreams of life are its chief realities."

Mr. S. Bayard Dod, President of the Board of Trustees, then conferred the degree of "Mechanical Engineer" upon the members of the class, 38 in number, and distributed the diplomas.

The names of the graduates, together with the subjects of their respective theses, are as follows:

ST. GEORGE M. ANDERSON. E. J. BURKE.
Test of Babcock & Wilcox Boiler with Various Kinds of Coal.

FREDERICK J. ANGELL. WILLIAM A. JONES.
Test of Triple Expansion Engines and of Boilers of Ocean Tug "Plymouth."

EDWARD P. BUFFETT, JR.
Electro-Magnetization of Nickel Steel.

BARTON H. CAMERON. HENRY D. LAWTON.
Comparative Test of a Slide Valve Engine and a Corliss Engine.

GEORGE W. COLLES, JR. EDWARD B. GALLAHER.
Test of an Electric Railway Power Station at West Haven, Conn.

H. DUDLEY COLEMAN, JR. JAMES M. COX. HENRY L. FRIDENBERG.
Test of the Electric Light Plant at Bloomingdale & Co.'s Store.

DAVID CORBIN.
Water Consumption of a 50 Horse-Power Ball & Wood Engine.

JOSEPH COTTIER. OLIVER ELLSWORTH.
Stresses and Strains in Gas Holder Framework.

WM. B. O. FIELD. GEORGE B. FIELDER, JR. MORRIS W. KELLOGG.
Test of Roney's Mechanical Stoker.

WILLIAM GIBSON. FREDERICK W. OPPERMANN.
ARTHUR M. LOZIER.
The Distribution of Power in the Waddell-Entz Storage Battery System, Second Avenue, New York City.

JOHN W. GILMORE. CHARLES W. MACCORD, JR.

Test of Water Consumption of Rollin's Engine Under Light Loads.

EDWARD GNADE. LOUIS RUPRECHT.

Test of Boilers and Engine of a Plant for the Manufacture of White Lead.

ROBERT P. HAMILTON. ALFRED KOLLSTEDE.

Test of a Dow Steam Turbine.

CHARLES C. HARTPENCE. JOHN B. KLUMPP. HENRY E. MCGOWAN.

Comparative Test of Electric Car Motors.

CHARLES C. KENYON. EDWARD D. MATHEY. RUSSELL E. TAYLOR.

Comparative Tests of Compound and Simple Locomotives on New Jersey Central Railroad.

WILLIAM D. PIERSON. ROBERT W. SMITH.

An Appliication of Exploring Coil for Determining Disturbing Elements in a Dynamic Field.

ERNEST PULSFORD. GILBERT ROSENBUSCH. WILLIAM E. SHOEMAKER.

Test of Ammonia Compression Ice Machine.

Mr. Dod announced that Mr. Charles F. Peck, '96, had won the Priestley Prize, and that two Stevens School scholarships had been awarded, as Messrs. Lewis Sanders and Herbert R. Davis had passed the competitive examination with so nearly equal grade as not to permit of discrimination.

An event not on the programme then excited the liveliest interest. President Morton announced that he had been requested to present to the members of the Intercollegiate Championship Lacrosse Team of 1894, souvenir pins provided by the students as a token of their appreciation of the successful efforts of the team. Amid hearty applause he presented the souvenirs to Mr. Kellogg. the Captain, to be delivered to the respective members of the team.

Mr. Oliver Ellsworth then delivered the

VALEDICTORY.

"*Mr. President, Members of the Faculty, Trustees, Friends, and Fellow Students:* The crowning event of our college course which you have honored with your presence is to us an occasion of the

gravest importance. It marks the end of a chapter in our book of life. It celebrates a victory won by years of earnest work. It opens to us a field in which we are to labor until He who gave us life sees fit to call us hence.

"You who are familiar with the curriculum of Stevens Institute know that our four years have been given over to an attempt to master the rudiments of one of the grandest professions of the age, and some of you know how hard we have struggled to gain the coveted prize which but a few minutes ago was bestowed upon us. To you we turn, knowing that you will congratulate us upon the successful termination of our labors here. We know, however, that the goal of our ambition is still far away, and what I have called a chapter in the book of life, might better be termed its preface. The book itself then depends upon our future. Will that future be successful?

"James Henry Hammond, in an oration delivered some years ago, before the Literary Societies of South Carolina College, said: 'If we pass in review all the pursuits of mankind and all the ends they aim at, we shall find that whatever is great or good in their deeds or purposes depends upon their intellect and is accomplished just in proportion as that intellect is stored with knowledge, and whether we examine the past or the present, we shall find that knowledge is a real power.' The extent of our power depends upon our ability to learn and to put to some practical use the knowledge which it has been our object the past four years to obtain. All our hours of worry and toil have had that end in view. Through the labors of our professors, who it seems have sometimes had to work fully as hard in imparting knowledge as we to imbibe it, we have acquired some knowledge and the ability to gain more, and we are thus in a measure equipped to meet the obstacles that are sure to encumber our road to success. And does not knowledge or power rightly used lead to friends, position, wealth, success, and happiness? Surely it does, or else the laws of nature would be reversed.

"With these thoughts before me, have I not a right to predict the above consequences as realities and not as iridescent dreams? Only time will tell, but I believe that the heading of the coming chapters in our book of life will be 'success,' and I hope that when that book is closed, 'a successful life' will be its appropriate title.

"*Mr. President:* It is with a feeling of deep and tender regret that we turn to you to say farewell. The thought that we are about to leave the familiar halls and kindly shelter of our Alma Mater, where many of our happiest hours have been spent under your supervision and guidance, makes the parting necessarily sad. The paths of knowledge, which we have trodden, have been made more easy by your kindness and that of those who are gathered about you. Quietly but firmly you have advanced us, until we have seen with our own eyes the depths of our ignorance, and it was not until these depths were fully sounded that we appreciated for ourselves the opportunities of knowledge that were before us. In the discharge of your duties you have presented to us an example of a devout Christain, an earnest instructor, and a kind-hearted friend. Those of us who have been so often deserving of your admonition have also found it mingled with regret from you. Most courteously have you entertained us and contributed to our social pleasures. You have made our interests your interests, our sorrows your sorrows. The fame of our Alma Mater owes much to your generosity, and we hope the day is not far distant when the means to enable you to advance her to a still higher degree of honor and usefulness will be forthcoming. In this, believe me, sir, the Class of '94 wishes you all possible success. Farewell!

"*Gentlemen of the Faculty:* Under your careful and ever watchful guidance we have been enabled to reach a goal which, four years ago, seemed so uncertain. You have given us your aid and your encouragement. Step by step you have interpreted to us the mysteries of nature and raised us in the scale of knowledge and virtue. You have awakened in us a thorough interest in the work of our profession, and words can but inadequately express our appreciation

of your earnest endeavors. The fact that we have to-night received our coveted degree will, in a measure, we hope, repay you for the hours you have devoted to us. Your calling is indeed high and holy. Your fame will be the property of nations. As Freshmen we feared you, as Sophomores we admired you, as Juniors our admiration rose to esteem, as Seniors we honored you, and now, as we pass from your guidance to take our place in the busy world, we thank you most heartily for the benefits you have bestowed upon us, and we part, hoping that the life of each one of you may be a long and happy one. May our Alma Mater for many years enjoy your efforts in her behalf. Farewell!

"*Classmates:* Four years ago we met as strangers and started together on the road of knowledge. Side by side we have gone on, sometimes loitering a little by the way, but oftener plodding on in line together. We have had many joys and sorrows in common. To-night the ties which have held us together so long are to be severed. Our roll has but a few minutes ago been called for the last time. It is with a feeling of deep sadness that we look back and compare this last roll-call with the first. What changes have taken place! What faces have been lost. There were then five among us who entered with our own hope and expectation, who, by the will of God, have been taken from us. One of our number died shortly after we entered college. Another was stricken down at the beginning of our Sophomore year. Two others were taken during our Junior year, and still another but a few weeks ago. Other classes have not been so unfortunate in this respect, yet we have the consolation that those of us who have been taken have already gone to their eternal home away from this world of strife and sorrow. Let us cherish their memory as friends, honor their efforts by emulation, and hope that many years may be spared to us, and that finally we may meet them in the glorious hereafter.

"This is indeed a solemn moment. We are standing to-night between the student's life of theory and the practical realities of a professional career. Have we a motto to aid us in the battle that

begins with the morrow's sun? Let me suggest one. Recently, when looking over an old autograph album, I found inscribed upon one of its pages, by a professor now passed away, these three words: '*Fortiter, Fideliter, Feliciter*' (Bravely, Faithfully, Happily), and beneath them this sentence: 'May this Latin motto be the motto of your life.' Surely, my classmates, it is worthy to be inscribed upon our banners.

"The four years of work, through which we have passed, have seemed to give us a certain standard, to clearly define the work we are to do, and to point out the difficulties which will meet us in our future. The profession we have chosen is not an easy one. Though of recent origin, as compared with other pursuits, there are already thousands of engineers, and we will make but a small addition to that vast army of veterans, whose example it would be well for us to imitate.

"Every one of us is expected to do a certain amount of work and to do it well. Should that work lie among peculiar circumstances, we are aided in it by knowing how others have contended in similar difficulties. Our problems will sometimes be stupendous, our opportunities not always the most alluring.

"We must remember that there are many problems in our future life which should interest us outside of our own beloved profession. As Christians, we owe a duty to our Creator and to our fellow men, and, as citizens of this mighty Republic, we owe many duties to our country, our State, and our city. The spirit of reform is in the air. Let us go out into the world and take our place in it as men who have at heart all good interests.

"Of our Alma Mater we should ever be proud, and we should follow her future with interest and, I trust, delight. Classmates, whatever may befall us in the future, and though years may elapse before we meet again, I feel sure we shall never forget each other.

"It is hard to speak the parting words. Farewells are, if not the least pleasant, among the least pleasant things of this life, but, nevertheless, from time to time they must be said. Let us each,

then, bid the other a hearty Godspeed, and go forth, remembering that 'The end of life is not money, but duty; the law of life is not competition, but co-operation; the bond of life is not self-interest, but brotherhood.' FAREWELL!"

The exercises closed with the benediction by Rev. Mr. Jenvey.

The musical part of the programme comprised:

OVERTURE,	"Stradella,"	VON FLOTOW.
SELECTION,	"Fencing Master,"	DE KOVEN.
MARCH,	"High School Cadets,"	SOUSA.
WALTZ,	"Symposia,"	BENDIX.
INTERMEZZO,	"Cavalliera Rusticana,"	MASCAGNI.
SELECTION,	"Carmen,"	BIZET.
SELECTION,	"Robin Hood,"	DE KOVEN.

And was so excellently rendered as to lead to earnest commendation.

The Commencement Committee included: George B. Fielder, Jr., William A. Jones, Barton H. Cameron, Frederick J. Angell, Charles W. MacCord, Jr., Robert W. Smith, Arthur M. Lozier, H. Dudley Coleman, Jr.

The Reception Committee, from the Class of '95, consisted of: F. V. Lawrence, W. H. Corbett, C. P. Paulding, Austin Greenidge, Latimer Carter, Thomas B. Cuming, Charles T. Church.

Reunions of several classes were held on Tuesday, the 19th.

'84 had an excursion to West Point by Albany Day Line steamer and return by Hudson River Railroad, with dinner at the Arena, Thirty-first Street, near Broadway, New York City, in the evening.

'89 met at the Arena at 8.30 P. M.

'91 held its triennial on the same day.

On Wednesday, June 20, Class of '88 mustered with well filled ranks at Meyers' Hotel, Hoboken, at 6 P. M., and with invited guests had a joyful reunion

ANNUAL MEETING OF THE ALUMNI ASSOCIATION.

THE annual meeting of the Alumni Association, held in the Hall of Stevens School, on June 20, was called to order by President Van Atta shortly after 9 o'clock.

The Recording Secretary being absent, Mr. Durand Woodman was appointed Secretary, pro tem.

On motion duly made and seconded the reading of the minutes of the previous meeting was dispensed with.

The Treasurer of the Association, Professor Bristol, read the following reports, which, on motion, were accepted:

TREASURER'S REPORT.

HOBOKEN, June, 20, '94.

To the Alumni Association of the Stevens Institute of Technology:

I.—GENERAL FUND.

Receipts.

Balance in Fund June 22, 1893	$86.85	
Dues for 1893–94	800.00	
Dues in arrears	163.50	
Dues in advance	10.00	
Stenographic report special Executive Committee meeting	4.50	
		$1,064.85

Expenditures.

Alumni subscriptions STEVENS INDICATOR to June, 1894,	$699.00	
P. E. Raqué, Corresponding Secretary, clerk hire, printing, and postage	123.20	
W. H. Bristol, Treasurer, printing, postage, and clerk hire	41.81	
Expenses, annual meeting, June 22, 1893	3.00	
Expenses, midwinter meeting, February 20, 1894	116.50	
Printing 1,000 copies Constitution	32.00	
Crayon portrait, E. B. Wall	41.00	
		$1,056.51
Balance in Fund June 20, 1894		$8.34

II.—Beneficiary Fund.

Receipts.

Balance in Fund June 22, 1893	$809.61	
On loan repaid	15.00	
Interest on loan	3 22	
Bank interest	39.50	
		$867
Balance in Fund June 20, 1894		$867
Amount of outstanding loans	$657.22	

III.—Library Fund.

Balance in Fund June 18, 1893	$114.75	
" " " " 20, 1894	114.75	

IV.—Library Portrait Fund.

Balance in Fund June 18, 1893	$1.72	
" " " " 20, 1894	1.72	

V.—The Stevens Indicator.

Receipts.

Balance June 18, 1893	$368.26	
From F. Angell, Business Manager	279.01	
" C. C. Hartpence, " "	293.75	
" Professor Graydon, Editor	40.81	
Alumni subscriptions to date	699.00	
		$1,680

Expenditures.

Publication April Indicator, 1893	$248.67	
" July " 1893	340.74	
" October " 1893	260.64	
" January " 1894	192.73	
Reprints, "Screw Propeller"	75.20	
Postage, expressage, and addressing Indicator	31.01	
Professor Graydon, editing Indicators, 1893-94	200.00	
Binding Indicators	16.40	
Drawings and cuts for Indicators	61.67	
Title pages	10.00	
		$1,437
Balance June 20, 1894		$243

Respectfully submitted,
W. H. Bristol, *Treasurer*

The Treasurer called attention to Section 4 of Article VII. of the Constitution, providing for the reading at this meeting of the names of members dropped. On motion duly seconded it was Resolved, That if the Treasurer is aware of a reasonable excuse for the non-payment of the dues of any member, the name of such member shall be excluded from the announcement now to be made.

The Treasurer then read a list of names of members dropped.

Professor Riesenberger, Treasurer of the Building Fund, reported nearly $10,000 collected.

The Chair reported that the Executive Committee had held several meetings, and had disposed of the matters requiring attention, including several matters which had held over from last year.

Mr. Humphreys, on behalf of the Alumni Trustees, stated that they had no report to make.

Upon motion duly seconded the Class of '94, as a body, was then elected to membership in the Association.

On motion by Mr. Bang, duly seconded, it was resolved "That names of members whose addresses are wanted, be published in the INDICATOR."

On motion duly seconded it was carried that persons dropped should be notified of the fact by the Treasurer.

Mr. Bang then moved "that the notices be sent by registered mail." Mr. Cuntz moved to amend by adding "and shall state that by payment of back dues, etc., the members dropped will be reinstated." Mr. Bang accepted the amendment, and the motion, having been seconded, was voted down, after the Treasurer had explained that three bills had already been mailed to each delinquent.

The Chair then stated that Mr. Wolff had been asked to make remarks in recognition of the loss of the Association through the recent death of Edward B. Wall, who but two years before had filled the position of President of the Association so acceptably, but that owing to illness Mr. Wolff could not be present. He had, however, sent the following letter, which was then read:

MY DEAR MR. VAN ATTA: NEW YORK, June 20, 1894.

I regret exceedingly that illness prevents my attending the Alumni meeting this evening; all the more, because you had counted upon my saying a few words in presenting the portrait of our much-beloved and lamented fellow member, Edward B. Wall.

I had known Ed. Wall long before we entered Stevens. We were neighbors in River Terrace, and, as boys, already were friends. In his career at college and in his career in actual life, it was the genuineness of his nature, his unflinching love and devotion to truth, his generosity of mind and heart, that called for my admiration, and which, I believe, was the keynote of his character, which made him esteemed by all who had the privilege of knowing and meeting him. Coupled with his fine nature, he possessed rare executive ability, and much shrewdness and exceptional common sense. His engineering experience necessarily became great, but, personally, I have never ascribed his exceptional success so much to special engineering equipment and talent, as to the qualities of mind and character, good judgment and common sense, which enabled him to put the engineering material in shape for practical use. He was an actual leader of men, and had his life not been cut off so early, the very highest executive offices in the gift of the Pennsylvania Railroad would doubtless have come to him in time.

I wish I could be with you this evening to add my little tribute to the abler ones which will be offered, and I wish in default of this that I had time now to write out the thoughts which fill my soul as I think of him. But while the feelings of respect, admiration, and love are present, the ability to clothe them in words is lacking at this hour. Nor does it matter who utters the word, so it be uttered. But it is well that men of this stamp do not pass away without our reading the lessons of their lives, and the career of Edward B. Wall, a graduate of Stevens, a member of the Alumni Association, a President of the Alumni Association, and a member of the Board of Trustees of the Institute, was one of such unblemished credit to the Institute and its organizations, that no words of mine, nor even of yours, could do it sufficient justice. To him peace has come. May peace be with those who mourn him most, and may his life teach to many graduates of Stevens the lesson that genuineness of mind and heart, and high honor, are the essentials of real success.

Sincerely yours, ALFRED R. WOLFF.

Mr. Kent was called upon to speak of his former classmate, and with much feeling reviewed briefly Mr. Wall's college and business careers; emphasizing the readiness with which Mr. Wall always did the work allotted him, however repulsive or discouraging it might be.

The Chair then, on behalf of the Alumni Association, presented to the Institute a crayon portrait of Mr. Wall, which had been prepared in order to obtain a suitable artotype portrait for the April issue of the INDICATOR.

President Morton, on behalf of the Institute, accepted the portrait, and mentioned that Dr. Dudley, of the Pennsyvania Railroad, had within a few days remarked that during his long connection with the road he had never known of such a case of so general and strong an expression of feeling by all classes as was witnessed at Mr. Wall's funeral. The train bearing his body to Columbus was repeatedly stopped at way stations by the employees, who desired to pass through the car for a last friendly look. Dr. Morton also alluded to the hardships Mr. Wall had manfully endured in working up from the lowly position to which he was at first assigned, and to the remarkably sympathetic character of the man, rendering everyone with whom he came in contact his personal friend.

The Chair then announced the result of the balloting for officers, as follows:

President.—William Hewitt, '74,	110	votes.
Ernest S. Cronise, '81,	71	"
First Vice-President.—Harry De B. Parsons, '84,	156	"
Paul Doty, '88,	24	"
Second Vice-President.—Adam Riesenberger, '76,	101	"
Benjamin F. Hart, Jr., '87,	78	"
Corresponding Secretary.—Phillip E. Raqué, '76,	112	"
Joseph Wetzler, '82,	69	"
Recording Secretary.—J. Day Flack, '87,	116	"
George Dinkel, Jr., '88,	63	"
Treasurer.—Adam Riesenberger, '76,	72	"

	William H. Bristol, '84, - - -	109 votes.
Directors.—Arthur A. De Bonneville, '78, - - -		102 "
	Harry Van Atta, '81, - - - -	91 "
	John M. Rusby, '85, - - - -	90 "
	A. P. Boller, Jr., '91, - - - -	78 "
Alumni Trustees.—J. Mather Wallis, '76, - - -		87 "
	F. E. Idell, '77, - - -	71 "
	Edward A. Uehling, '77, - -	8 "
	George M. Bond, '80, - -	61 "
	Durand Woodman, '80, - -	67 "
	Roland S. Kursheedt, '80, - -	6 "
	Harry Van Atta, '81, - - -	22 "
	Joseph Wetzler, '82, - - -	43 "

And declared the following officers elected for the ensuing year:

President.—William Hewitt.
First Vice-President.—Harry De B. Parsons.
Second Vice-President.—Adam Riesenberger.
Corresponding Secretary.—Phillip E. Raqué.
Recording Secretary.—J. Day Flack.
Treasurer.—William H. Bristol.
Directors for two years.—Harry Van Atta.
John M. Rusby.
Directors for one year.—William Sheldon.
Joseph A. McElroy.
Alumni Trustees.—F. E. Idell.
Durand Woodman.

On motion duly seconded and carried the meeting then adjourned.

MEMBERS IN ATTENDANCE.

President Henry Morton.
Prof. C. W. MacCord.
" J. E. Denton, '75.
" W. E. Geyer, '77.
Ass't Prof. A. Riesenberger, '76.
" W. H. Bristol, '84.
" D. S. Jacobus, '84.
" S. D. Graydon, '75.
" G. L. Manning, '91.
James M. Cremer, '76.
G. C. Henning, '76.
William Kent, '76.
Frank E. Idell, '77.
E. P. Thompson, '78.
J. W. Lieb, Jr., '80.
D. Woodman, '80.
A. C. Humphreys, '81.
H. Van Atta, '81.
J. Wetzler, '82.
M. McNaughton, '83.
W. L. Lyall, '84.
E. Burhorn, '85.

C. E. Machold, '85.
C. J. Field, '86.
F. E. Jackson, '86.
G. R. Metcalfe, '86.
J. H. Cuntz, '87.
B. F. Hart, '87.
F. Moeller, '87.
W. E. Parsons, '87.
H. A. Bang, '88.
N. St. G. Campbell, '88.
George Dinkel, Jr., '88.
Paul Doty, '88.
E. M. Drummond, '88.
Edward Ducommun, '88.
A. S. Miller, '88.
J. V. L. Pierson, '88.
H. E. Reeve, '88.
D. H. Gildersleeve, Jr., '89.
F. Gubelman, '89.
W. D. Hoxie, '89.
R. C. Oliphant, '89.
Chas. J. Everett, '90.
E. H. Peabody, '90.
G. L. Todd, '90.
H. Torrance, Jr., '90.
W. S. Ackerman, '91.
A. P. Boller, Jr., '91.
B. W. Carll, '91.
L. H. Nettleton, '91.
G. S. Perkins, '91.
F. Gardiner, '92.
H. W. Jackson, '92.
Frank E. Law, '92.
H. Lowenherz, '92.
W. O. Ludlow, '92.
W. E. S. Strong, '92.
H. H. Adams, '93.
A. B. Brookfield, '93.
A. E. Bruen, '93.
O. G. Dale, '93
F. D. Furman, '93.
H. E. Griswold, '93.
H. Kopp, Jr., '93.
E. D. Lewis, '93.
A. B. Lord, '93.
C. T. Rittenhouse, '93.
A. G. Wilbor, '93.
F. J. Angell, '94.
E. P. Buffet, Jr., '94.
G. B. Fielder, Jr., '94.
H. L. Fridenberg, '94.
C. C. Hartpence, '94.
W. A. Jones, '94.
M. W. Kellogg, '94.
H. D. Lawton, '94.
G. Rosenbusch, '94.

EXTRACTS FROM THE ENGINEERING PRESS.

HENRY MORTON.—"It would be quite impossible within the limits of this article even to give the titles of President Morton's contributions to scientific literature. His researches have been chiefly on the subjects of chemistry and of light, though many other fields have been locally cultivated by him. Soon after his settlement at Hoboken he was called upon to advise and assist, as a scientific expert, in an important patent litigation, and the efficiency of his investigation in this case soon led to his being called upon in others, also involving difficult scientific problems, and thus he soon gained and has since held the position of leading scientific expert in New York and its vicinity, and the revenue derived from this class of professional work has enabled him to contribute to the growing needs of the Stevens Institute of Technology, not only by the large donations already noted, but by many others involving less amounts, but large in the aggregate, and of enhanced practical value from their timely application.

"One of the most prominent stenographers employed in the New York courts once said to the present writer: 'We have less trouble in taking down President Morton's testimony than with that of any other witness. He always says what he means, and sees his way ahead so far that if there are ambiguities or forms of expression likely to lead to confusion in the questions put to him by the lawyers on either side, he always straightens them out in the first instance, and so avoids the confusion which often arises from a lack of clear statement. He loses no time in making his answers, and thus, without hurry, gets through a vast amount of work in a day.'

* * *

"The taste for drawing which led Mr. Morton in his college days to illuminate the Rosetta Stone Report, continued to prove useful to him in his subsequent work. While editor of the Franklin Institute *Journal* he frequently drew on stone illustrations required for that publication, and constantly prepared pictures or diagrams for the illustration of his lectures.

"In later life he has been able to gratify his artistic taste by collecting a number of paintings by our best American artists of the non-impressionist school, such as Hertzog, McCord, Ferguson, Bricher, Craig, Turner, Hawley, and Davis, which delight all those who take pleasure in what is intrinsically beautiful. In the *Century Magazine* for December, 1890, and for May, 1893, will be found examples of a poetic vein which casual acquaintances would not have suspected, but which has often been a source of pleasure to his intimate friends."—*Prof. Coleman Sellers, E. D., in Cassier's Magazine, August*, 1894.

THE FERRYBOAT OF TO-DAY.—"I shall stop you a moment and ask you to step on the upper deck of a New York ferryboat. You must not expect me to ask you into the pilot house, as, unless you have a pilot's license, the law forbids it, and if we should have a collision the court may think that you 'rattled' the pilot and mulct our boat in damages. Now look around and see the everyday life of the lower Hudson. There to the southward you will see an ocean tramp threading his way along. Astern are a steam lighter and a tug with a car float in tow, while a couple more tugs are hunting around for jobs, like beagles searching for a trail. The giant 'Campania' is backing out of her berth, her monster stacks witnessing the industry of her stokers, who are now beginning to shovel coal to again lower the eastbound record. A Sound steamer is making her pier further down, while one of the steamboats bound for Coney Island is rushing downstream, and an excursion tow is heading slowly for Glen Island. In between them all, steadily and surely, a dozen ferryboats are carrying their human freight to do the daily work of the great metropolis. All this is crowded into a square mile of water which itself is moving to or from the sea at 2½ miles an hour.

"Now think of the problem set to the ferryman. He must carry in safety, across this crowded harbor, with its rapid and changing currents, a large portion of the business population of one of the world's great centers of business. It is estimated that the yearly passenger trips between New Jersey and New York number 70,000,000; that the total for all New York ferries will exceed 170,000,000; that the number of teams carried is 5,000,000. This safety can be secured only by a combination of good discipline and management with good boats; and good boats are those which not

only can withstand the effects of a collision, but which, better still, are able to avoid it and to come uninjured out of a tight place.

"You want, therefore, first of all, stopping power; after that some other qualities, as handiness in steering, quickness in starting, and ice-fighting qualities; but above all, and again, stopping power. The man who pays the bill will add economy in first cost and operation. These are the data of the designer. Everyone will be perfectly content if the boat can make 12 or 13 knots on her trial trip, and hold the same number of statute miles at full speed on her route. The engineer must have an engine that he can repair quickly and cheaply, and that will do the backing when called on, and not stick on centers or churn up the water uselessly. The hull must be well shaped, so that it will steer quickly, and will not sink at the bow when loaded by the head. It must be good for ice work, with easy lines, and, above all, must be staunch and strong and as nearly unsinkable as skill and money can make it.

* * *

"The nine North River screw boats built thus far are the finest fleet of ferry craft the world has yet seen. They can and do carry their passengers at a speed, with a degree of comfort, safety, and regularity, unequalled before their day; the thickest ice and the heaviest gales have not thrown them behind their schedule; the small number of accidents they have met, and the comparative immunity of their passengers from injury in those that have happened, attest their safety, while their unquestioned popularity is the best evidence that they render the public good and acceptable service."—*Col. E. A. Stevens, in Cassier's Magazine, August*, 1894.

Comparison of Different Formulæ for Dimensions of Parts of Steam Engines.—"The writer has had occasion to study the formulæ for dimensioning of parts of steam engines given by different writers, especially those given by Rankine, Thurston, Marks, Whitham, and Seaton.

"For the purpose of making a comparison of the formulæ it was considered advisable to test them by applying them to several assumed cases, covering a very wide range of sizes. Three diameters of cylinders were selected—viz., 10, 30, and 50 inches, with indicated horse-powers, for about the most economical load, of 50, 450, and 1,250. A short-stroke and a long-stroke engine of each size were taken, the short stroke having a length about equal to the

diameter, and the long stroke a length about equal to two diameters.

"The results of these tests of the different formulæ showed in many cases a wide divergence; thus, for thickness of cylinder of the 10-inch engine, they range from .33 to 1.13 inches, and of the 50-inch engine from 1.56 to 3 inches; for thickness of cylinder head of the same engines the range is from .30 to 1.15 inches and from 1.50 to 2.75 inches.

"The principal formulæ and the results of the study in condensed form are given below. Many formulæ which are not given below were rejected during the study, either as practical duplications of other formulæ given in other forms, or because they gave results far outside of the range of probability"—*William Kent, M. E., '76, in American Machinist, July 26, 1894.*

THE IDEAL PREPARATORY SCHOOL FOR ENGINEERING STUDENTS.—"What preparatory training should a student have before entering an engineering school? The preparatory training must be, of course, such as will fit the student to pass the entrance examinations of the technical school, and such as will give him sufficient mental discipline to enable him to pursue its courses. The minimum possible preliminary training would be an ordinary grammar school education plus mathematics up to that point at which the freshman class in the technical school begins. The desirable amount, however, is far greater even to the extent of including an ordinary four-year academic or collegiate course, and in the case of the mechanical engineering student, some workshop experience.

"What should be aimed at by a preparatory school is a compromise between these two extremes. If it gives the student only such training as will fit him to enter the technical school and to pursue its studies, his education is likely to be one-sided and narrow, and when he graduates he will not have that broad foundation of general culture which the modern profession of engineering requires. If, on the contrary, it gives him the old-fashioned collegiate course, with four years of Greek and Latin, intellectual philosophy, ancient history, and the like, much of his time will be wasted on mental padding, which is not necessary either for mental discipline or for general culture, and is entirely useless as a professional equipment of an engineer."—*William Kent, '76, in Cassier's Magazine, August, 1894.*

THE CHAMPIONS OF THE INTER-COLLEGIATE LACROSSE ASSOCIATION.

IT is with quickening pulse and brightening eye that Stevens men, the world over, learn of high achievement by Stevens students, whether it be in their college work, in their inter-collegiate sports, or in their contact with the duties and opportunities of professional life.

Such an achievement is the winning of the proud position of Champions of the Inter-collegiate Lacrosse Association by Stevens team of 1894.

The records of the members of the team as published in *Stevens Life* are given herewith, and a picture of The Champions will serve to introduce them to Stevens Alumni, from all of whom they are entitled to a cordial greeting wherever met.

MORRIS W. KELLOGG, '94, captain, of Elizabeth, N. J., is 20 years old, 5 feet 11 inches tall, weighs 155 pounds, and plays 1st attack. His first experience at lacrosse was in his Freshman year, playing in the 'Varsity ever since, and being unanimously elected captain for the year just passed. He has played in his class foot-ball and lacrosse teams, and was captain of the class lacrosse during his Sophomore year. He played on the 'Varsity foot-ball team last fall.

W. H. CORBETT, '95, of Brooklyn, N. Y., is 24 years old, 5 feet 10 inches tall, and weighs 165 pounds. He plays point, and has played on the 'Varsity since entering college. He has played in all the class teams, and was captain of the Sophomore lacrosse team. He played on the 'Varsity foot-ball team last fall. He has been unanimously elected captain of the team for next year.

GEORGE B. FIELDER, Jr., '94, of Jersey City, N. J., is 23 years old, 5 feet 10½ inches tall, and weighs 160 pounds. He plays 3d defense on the team, and has played for two years, besides playing in all the class teams, being captain of the Freshman base-ball team. He has played on the 'Varsity foot-ball team for three years, and played on the Preparatory team of '89.

CHAMPIONS OF THE INTER-COLLEGIATE LACROSSE ASSOCIATION.

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TILDEN FOUNDATIONS

C. W. MacCord, Jr., '94, of Hoboken, N. J., is 20 years old, 5 feet 5 inches tall, and weighs 160 pounds. He plays outside home and 1st attack, and has played on the 'Varsity since entering college. He has also played on the 'Varsity foot-ball team for four years, and all the class teams, besides the Preparatory team of '88.

E. Hutchinson, '95, of Brooklyn, N. Y., is 22 years old, 6 feet tall, weighs 165 pounds, and plays inside home. He has played for three years on the lacrosse team, and for three years on the foot-ball team, besides the various class teams.

Howard H. Maxfield, '95, of Elizabeth, N. J., is 20 years old, 5 feet 7½ inches tall, and weighs 135 pounds. He plays 1st defense, and has played on the 'Varsity team ever since entering college, beside class base-ball, foot-ball, and lacrosse teams.

Pascal N. Strong, '96, of Savannah, Ga., is 19 years old, 6 feet 2 inches tall, weighs 175 pounds, and plays cover point. He has played on the team for two years, besides the class lacrosse team.

W. E. Jennings, '96, of South Orange, N. J., is 20 years old, is 5 feet 6 inches tall, and weighs 138 pounds. He plays center, and this is his first year on the 'Varsity, although he has played two years on his class team.

F. H. Coyne, '94, of East Orange, N. J., is 21 years old, 5 feet 10½ inches high, weighs 165 pounds, and plays goal, which position he has held for four years. He has played on the 'Varsity foot-ball team for four years, and was captain the last two, and was also captain of his class team during the Sophomore year. He is captain of the O. A. C. foot-ball team for next year. He has played on all his class teams, and was captain of the Preparatory School base-ball team of '90.

T. E. Jewell, '95, of Brooklyn, N. Y., is 22 years old, 5 feet 6½ inches tall, weighs 140 pounds, and plays 3d attack. He has played for two years in the 'Varsity, besides playing on his class lacrosse team for two years.

A. E. Whitman, '96, of Brooklyn, N. Y., is 21 years old, 6 feet 1 inch tall, and weighs 160 pounds. He plays 2d defense, and has played one year. He has played for two years on his class lacrosse team.

R. E. Bruckner, '96, of Hoboken, N. J., is 19 years old, 5 feet 5 inches tall, weighs 138 pounds, and plays 2d attack. This is his first year on the 'Varsity, though he has played on his class lacrosse team for two years, being captain of Freshman year.

Ross S. Scott, Jr., S. S., of Baltimore, Md., is 18 years old, 5 feet 6 inches high, and weighs 140 pounds. He played inside home. This is his first year on the 'Varsity, though he played on the 'Varsity base-ball team for two years, was captain of the Preparatory School team for three years, and captain of the Preparatory School lacrosse team the present year.

ATHLETICS.

LACROSSE.

In spite of the prophecy of that most eminent authority on college athletics, Caspar R. Whitney, that all hopes for the furtherance of lacrosse interests in American colleges would depend upon Lehigh and Johns Hopkins Universities, at the close of this season of 1894 we can look back upon sweeping victories for Stevens on all sides. One new banner already decorates the walls of our library, and before long they will be still further embellished by the Championship Banner of the Intercollegiate Lacrosse Association for 1894.

The games played were as follows:

April 21,	at Hoboken;	Stevens 3, Crescent A. C., 6.
May 1,	" Bay Ridge;	" 1, " " 3.
" 9,	" Ithaca;	" 4, Cornell University, 1.
" 12,	" Hoboken;	" 7, Johns Hopkins University, 5.
" 19,	" Orange;	" 2, Cresent A. C., 4.
" 26,	" South Bethlehem;	" 3, Lehigh University, 2.
" 30,	" Jersey City;	" 1, Crescent A. C., 0.

Stevens *vs.* Crescents.—The lacrosse season was opened by two games with the team of the Crescent Athletic Club, and two other games, besides practice games, were played with that club. In all these games except the last Stevens was defeated. The last one was played in connection with the Decoration Day games of the New Jersey Athletic Club. Either the inspiration due to the presence of 5,000 spectators or a determination to close the season by defeating their most powerful rivals helped the team to work and win, and when time was called Captain Kellogg was presented with a very handsome banner, which is now to be seen hanging in the library.

Stevens *vs.* Cornell.—The team started for Ithaca on the evening of Monday, May 8. Cornell had already defeated Johns Hopkins, and the Cornellians had great expectations of success with Stevens, but they were doomed to disappointment, for the Stevens defense proved to be almost impregnable to their attack. Though Cornell, also, had a strong defense, the Stevens attack were able, by some skillful tipping and passing, to score four goals.

The teams lined up as follows:

Stevens.		*Cornell.*
Coyne	Goal	Findlay.
Satorious	Point	Taylor.
Strong	Cover point	Douney.
Whitman	1st defense	Tobin.
Hutchinson	2d "	Osborne.
Fielder.	3d "	Franchot.
Jennings	Center	Bell.
Jewell	3d attack	Oura.
Bruckner.	2d "	Powell.
Kellogg (Capt.)	1st "	Purman.
MacCord	Outside home	Leighton.
Scott	Inside "	Swindells.

STEVENS *vs.* JOHNS HOPKINS.—The first game of the championship series of 1894 was won by Stevens on Saturday, May 12, by a score of 7 to 5. The game was characterized on the part of both teams by an inability to pick up the ball, and, consequently, by a great deal of shinney. Nevertheless, Stevens did brace up occasionally, and it is significant that all their seven goals were scored at these phases of the game, and by good clean shots, while those of Hopkins were scored by their massing their attack about the Stevens goal and batting or kicking the ball between the posts. The defense did not cover as well as they might have done, and at times the Hopkins attack played all around them, securing a great many shots for goal.

The positions were filled as follows:

Stevens.		*Johns Hopkins.*
Coyne	Goal	Crenshaw.
Corbett	Point	Penniman.
Strong	Cover point	Dawson.
Whitman	1st defense	Mitchell.
Bruckner	2d "	F. K. Cameron.
Fielder	3d "	Straus.
Jennings	Center	Janney.
Jewell	3d attack	Roszel.
Kellogg (Capt.)	2d "	T. Cameron (Capt.)
MacCord	1st "	Hodges.
Scott	Outside home	Boude, B.
Hutchinson	Inside "	Hill.

Hopkins takes the ball, and with the sun at their backs they try twice for goal. Bruckner gets the ball and passes to MacCord, who scores Stevens' first goal within three minutes after the ball was faced. After some shinney play Coyne stops the ball again and Corbett passes it up the field. Hopkins throws wildly, Jennings plays well, and Penniman saves Hopkins' goal. The ball travels around the field some time, until Jewell passes from the center to Kellogg, who puts it easily between the posts.

scoring Stevens' second goal. Within five minutes Jennings scores the third. Penniman again saves Hopkins' goal, and shortly after Straus scores for Hopkins. After Kellogg scores the fourth the ball is kept for 10 minutes about Hopkins' goal, but wild throwing on the part of Stevens and good play for Hopkins by Crenshaw and Dawson prevents Stevens from scoring. The ball finally goes to Coyne again; he stops it, but Hill shoves it through in a scrimmage. The first half ends here, the score being: Stevens, 4; Hopkins, 2.

The second half begins by T. Cameron scoring for Hopkins. The ball now oscillates several times from goal to goal, trials being made by both sides, and Boude finally scoring for Hopkins, tieing the score. Stevens again rises to the emergency, Kellogg and Scott each scoring a goal. The play here grows very brisk, and continues so until the end of the game, before which each side scores one more goal, making the score: Stevens, 7; Hopkins, 5.

The umpires were Mr. H. Boude, of Johns Hopkins, and Mr. Martin, of Stevens, '92. The referee was Mr. Evans, of the New York A. C.

STEVENS *vs.* LEHIGH.—The final and deciding game of the lacrosse championship series of 1894 was won by Stevens at South Bethlehem, Pa., on Saturday, May 26, by a score of 3 goals to 2.

The annual inspection trips of the Stevens Juniors and Sophomores were arranged in such a way that over one hundred men were on hand to cheer for Stevens. The presence of all these men in town on Friday and Saturday must have aroused considerable interest in the game, for the grand stands were filled and all the standing room occupied.

The game is said to have been the most exciting ever played on the Lehigh field. The playing was clean and quick, many brilliant plays being made by both teams, and from start to finish neither side could feel assured of victory. The defense of each team was better than its attack, but the Lehigh attack did some very pretty and effective tipping and passing, keeping the Stevens defense extremely busy, and it was evident that Stevens grit, rather than fine play, won the game.

The teams were as follows:

Stevens.		*Lehigh.*
Coyne	Goal	Buell.
Corbett	Point	Dick.
Strong	Cover point	Roderick.
Maxfield	1st defense	Ordway (Capt.)
Whitman	2d "	Polhemus.
Jewell	3d "	Dornin.
Jennings	Center	Kip.
Fielder	3d attack	Massey.
Kellogg (Capt.)	2d "	Baldwin.
Bruckner	1st "	Coleman.
MacCord	Outside home	Hilliard.
Hutchinson	Inside "	Van Maur.

Stevens took the east goal, and the ball was faced at 3.35 P. M. The play was very close for the first quarter of an hour, until Van Maur, in the absence of Coyne from goal, scored Lehigh's first goal. Stevens appeared rattled, and things looked black when Hilliard, within 10 minutes, scored the second goal for Lehigh. It proved to be the last, however, for Stevens began to put up a splendid game, and it was not long before Kellogg succeeded, by some clever dodging, in scoring Stevens' first goal. For the remainder of the first half neither side scored and it ended with the score: Stevens, 1; Lehigh, 2.

The second half was an exhibition of fine play and close play, for, though Lehigh did not score again, they often came very close to doing so, and gave Coyne several opportunities to stop the ball. Early in the half MacCord tied the score on a pass from Kellogg, to the evident relief of all the Stevens contingent on the bleaching boards, and soon afterwards MacCord gave Stevens the lead by a long throw past several of the Lehigh defense. This was the last goal scored and it gave Stevens the Championship, though no one could feel sure of that until the referee blew his whistle 25 minutes afterwards.

The umpires were Messrs. Floyd and Satorious, and the referee Mr. Roberts, of the Crescent A. C.

FOOT-BALL.

The delegates of the Middle States Foot-ball League met at the Astor House Tuesday, May 22, at 2 P. M. Lafayette was represented by Captain Strader and Manager Miller, Rutgers by Manager Lefferts, and Stevens by Captain Kemble.

Mr. Strader, of Lafayette, was elected President for the ensuing year, and Mr. Kemble, of Stevens, was elected Secretary-Treasurer.

The following schedule of games was arranged:

Lafayette *vs.* Rutgers, at New Brunswick, Saturday, October 6.

Rutgers *vs.* Stevens, at Hoboken, Wednesday, October 17.

Stevens *vs.* Lafayette, at Easton, Saturday, October 27.

FIELD GAMES.

Owing to the lack of financial aid the Board of Directors of the Athletic Association abandoned the project of awarding medals to the winners in the Field Day contests, and also decided not to compete this year with Rutgers. The annual field games were held on June 1. But few entries were made, and little interest was manifested by the few spectators present. The results, ridiculous as they were, are given below:

One hundred-yard dash—1st, Jennings, 10⅘ seconds; 2d, Harrison; 3d, Hewitt.

Two hundred and twenty-yard dash—1st, Jennings, 24⅕ seconds; 2d, Hewitt; 3d, Kennedy.

Four hundred and forty-yard dash—1st, Chambers, 64 seconds; 2d, Kemble.

One hundred and twenty-yard hurdle—1st, Strong, 16¼ seconds; 2d, Craft; 3d, Hollingsworth.

Three-legged race—1st, Kemble and Harrison, 13⅛ seconds; 2d, Whitman and Strong; 3d, Hunt and Gunnison.

One-mile run—1st, Chambers, 5 minutes 30 seconds; 2d, Munby; 3d, Leber.

Lacrosse ball throw—1st, MacCord, 320 feet 5 inches; 2d, Corbett; 3d, Strong.

Base-ball throw—1st, Hardie, 316 feet 4 inches; 2d, Cooper; 3d, Hunter.

Putting the 16-pound shot—1st, Kemble, 30 feet 11½ inches; 2d, Whitman; 3d, Corbett.

Throwing the hammer—1st, Corbett, 70 feet; 2d, Cooper; 3d, Whitman.

Running broad jump—1st, Kemble, 17 feet, 10½ inches; 2d, Bruckner; 3d, Hunt.

Running high jump—1st, Strong, 5 feet 1 inch; 2d, Corbett; 3d, Lent.

Standing broad jump—1st, Gunnison, 9 feet 2 inches; 2d, Fielder; 3d, Strong.

The officers of the day were: Referee, J. H. Cuntz; Judges, M. E. Craft, H. D. Lawton; Timers, Prof. F. Lawton, M. W. Kellogg; Starter, Dr. F. L. Sevenoaks; Clerks of Course, R. E. Hall, Latimore Carter; Measurers, F. V. Lawrence, L. Becker; Announcer, A. A. Dal Molin.

INSTITUTE NOTES.

In a decision recently rendered by His Honor Judge Dallas, of the U. S. Circuit Court, the claims of a patent on a water meter invented by L. H. Nash, M. E., of '77, have been sustained.

President Morton acted for Mr. Nash as expert witness in this suit, and in his "opinion" Judge Dallas says: "The testimony of Dr. Morton, and the experimental tests made and recounted by him, fully satisfy me that the disk-shaped skeleton of the defendant is identical, in the sense of the patent law, with the ring-shaped skeleton shown in the patent."

It is by no means usual to find the decision of a judge referring to an expert witness by name and we are informed that in the opinion of the lawyers conducting the suit for Mr. Nash, President Morton's experiments won this case.

Electricity of June 27 has an illustration showing the members of the International Niagara Commission, of which Dr. Coleman Sellers is so prominent a member.

FRANCIS GEORGE BRANDES, a member of the class of '96, while out in a yacht with a friend on Long Island Sound near Good Grounds, fell overboard and was drowned on July 18. His body was recovered, and the funeral service was held at the home of his parents, 142 West One Hundred and Twenty-second Street, on Saturday, the 21st, when a number of his classmates, among whom he was both esteemed and popular, were present.

IN MEMORIAM.

FRANCIS GEORGE BRANDES, '96.

Whereas, It has been the will of Almighty God to take from us our beloved friend and classmate, FRANCIS GEORGE BRANDES; and

Whereas, We, the Class of Ninety-six ('96) have lost in him a classmate whose noble and unselfish character has won for him our deepest love and respect, and whose death has caused us sincere sorrow; be it therefore

Resolved, That we express our grief by these resolutions, which shall be preserved in the annals of the class, and which shall appear in the Stevens publications; and be it also

Resolved, That in token of our deep sympathy for his bereaved family we tender them a copy of these resolutions.

BAYLIES C. CLARK.
W. CULLEN MORRIS.
RUDOLPH E. BRUCKNER.
Committee.

IN THE Department of Mechanical Drawing the experiment has this year been tried of requiring each student in the Freshman Class to pass an examination on the first 62 pages of "Practical Hints for Draughtsmen" before undertaking his sketching exercise in the Supplementary Term. The result has demonstrated the desirability of compelling, by such examinations, attention to the principles and illustrations set forth in the text-book. Better average work has been done, and with less expenditure of time by the students.

INSTITUTE PERSONALS.

It is our endeavor to notice under this heading such items of news affecting graduates of the Institute as may interest their classmates and friends among the Alumni. We are indebted to a few members for regular or frequent contributions of items, and wish to make it known that the co-operation of all is most desirable, and will be appreciated. MANAGING EDITOR.

'76.

WILLIAM KENT, who has had occasion to study the formulas for dimensioning of parts of steam engines given by prominent writers on the subject, has found these formulas to frequently give results widely divergent, and has begun the publication in the *American Machinist* of a "Comparison" of these formulas which should greatly facilitate the selection of the fittest by students in engine design.

'81.

ALEX. C. HUMPHREYS has announced his intention of resigning his position as General Superintendent of The United Gas Improvement Co., to take effect August 1, and of then devoting his energies to the interests of his firm, Humphreys & Glasgow, which has been operating in Europe for the past year, and for which he will open a New York office.

ALBERT SPIES gives an interesting account, elaborately illustrated, of an ascent of Pike's Peak by rail in the June number of *Cassell's Magazine.*

'82.

PIERCE BUTLER in May closed his connection with the Louisville and Nashville Railroad, with which he had been four years Chief Draughtsman and Mechanical Engineer, and is spending the summer in Europe.

'84.

KENNETH TORRANCE was appointed Engineer at the Ridgewood pumping station of the water-works of the city of Brooklyn, N. Y., on August 1 by City Works Commissioner White.

Mr. White had applied to the Civil Service Commission for an eligible list of chief engineers, and an examination was held. There were 23 applicants, of whom four failed to appear, four withdrew while the examination was in progress, one was canceled, 10 failed to pass with 70 per cent. to their credit, and only four secured places on the eligible list. Commissioner White has appointed Kenneth Torrance, of No. 184 Columbia Heights, who secured 92 per cent., and stood at the head of the list.

He was graduated at the Stevens Institute in Hoboken in 1884, and has had an office in Chicago recently. The salary of his new office is $2,500 and a house. Mr. Torrance is 31 years old and recently married.

'85.

JOSEPH S. MCCOY, Jr., received the degree of Master of Laws from the Georgetown University on June 11 at the Academy of Music, Washington, D. C.

RICHARD H. RICE is Treasurer of the newly incorporated Rice & Sargent Engine Company, of Providence, R. I., which has been organized to build the Rice & Sargent engine. This engine is described as a "four-valve automatic cut-off engine having rotary Corliss valves, double-ported, provided with a trip gear, and especially designed for electric and cable plants, mills, and other work requiring an engine fitted for heavy and continuous service and close regulation of speed."

After graduating Mr. Rice was draughtsman with the Bath Iron Works for one year; and for three years was Chief Draughtsman for E. D. Leavitt, for whom he designed some very ponderous engineering work. For the past four years he has been the Mechanical Engineer and Superintendent of the William A. Harris Steam Engine Company, of Providence.

Mr. John W. Sargent, the Secretary of the new company, has had extensive experience with the William Cramp & Son's Ship and Engine Building Company, E. D. Leavitt, and the Dickson Manufacturing Company.

The President, Mr. R. A. Robertson, and the Vice-President, Mr. Z. Chafee are respectively Treasurer and President of the Builders Iron Foundry, of Providence.

'86.

EDWIN J. COOK has removed to Cleveland, O., to take charge of the construction work of a large station. His address is care of the Cleveland General Electric Company.

EDWARD F. WHITE is acting as consulting engineer on general work. His address is 124 First Street, Bayonne, N. J.

C. J. FIELD, having taken the business of the Field Engineering Company into his own name, remains at his former address, 143 Liberty Street, New York, as consulting and supervising engineer.

'87.

MATTHEW C. JENKINS has been elected to full membership in the American Society of Mechanical Engineers. In January he severed his connection with the firm of Post & McCord, with which he had been nearly five years as Draughtsman and Superintendent, and is now Engineer and Agent for Coxe Iron Manufacturing Co., Drifton, Pa.

FRANKLIN MOELLER may be addressed at 336 West Twenty-ninth Street, New York.

'88.

HENRY A. BANG has been promoted to full membership in the American Society of Mechanical Engineers.

ALTEN S. MILLER is Engineer of Works for the East River Gas Company at Ravenswood, Long Island City, N. Y.

JOSEPH A. MCELROY is in charge of the work of C. J. Field at Bridgeport, Conn.

FRITZ UHLENHAUT, Jr., for the past year has filled the position of Chief Electrical Engineer with the Philadelphia Traction Company.

'90.

LUIS R. MENDOZA is General Manager of the Electric Light Company of Oaxaca, Mexico.

'91.

JOHN M. HANSON has recently completed the 1,200 000 cubic feet water gas plant erected under his supervision by the United Gas Improvement Company for the New Orleans Gas Company.

LLOYD H. NETTLETON was married on February 1 to Miss Reba Hedges, at the home of the bride, Hoboken, N. J., by Rev. W. R. Jenvey.

'92.

LUCAS FERNÁNDEZ received on May 18 from the President of Costa Rica, at San José, the appointment of General Manager of the Pacific Railroad, and General Superintendent of Public Works, with a salary of $3,000.

EDWARD L. JONES and Miss Lizzie J. Thompson were married at the home of the bride's father, Mr. S. C. Thompson, Westfield, N. Y., on Thursday, August 9, by the father of the groom, Rev. F. C. Jones, of Newark, N. J.

F. E. LAW holds a position as inspector in the Fidelity and Casualty Company Employers' Liability, of 140 Broadway, New York City. He is connected with the departments of steam boiler and elevator insurance.

GEORGE H. MILLER is with the Middle States Inspection Bureau, which is an association of fire insurance companies for the inspection of large plants.

'93.

O. G. DALE has been in the drawing room of the National Sugar Refining Company, Yonkers, N. Y., since graduating. He has been elected a Junior member of the American Society of Mechanical Engineers.

A. E. MERKEL is with the Fairfield Copper Company, at the works at Monroe, Conn.

SUBJECT CATALOGUE OF GRADUATION THESES IN THE LIBRARY OF THE STEVENS INSTITUTE.

VOL.

AIR:

Transmission of Power by Compressed Air.* ZAHNER, '78, - 39

Compound Air Compressors. VAN ATTA, '81, - - - 78

ALLOYS:

On the Properties of Triple Alloys of Copper, Tin, and Zinc.† COSTER, '77, - - - - - - - - - 30

Researches on the Triple Alloys of Copper, Tin, and Zinc.‡ JOBBINS, '82, - - - - - - - - 82

ALUMINIUM:

Electrical Properties of Aluminium. LIENAU, '91, - - - 183

BALLOONS:

Propulsion of Balloons (Present Status and Promise). SINCLAIR, '84, 116

BATTERIES:

The Distribution of Power in the Waddell-Entz Storage Battery System, 2d Avenue, New York City. GIBSON, LOZIER, AND OPPERMANN, '94, - - - - - - - - 193

BOILERS:

Test of Pittsburg Boiler and Engine. FISCHER, '85, - - 150

Boilers, Material and Manufacture of. WALTON, '87, - - 167

Experimental Test of a Worthington Pump and Boiler at High Service Pumping Station, 99th Street and 9th Avenue, New York City. METCALF AND MORTON, '86, - - - - 161

Experimental Test of Worthington Pump and Boilers with Special Reference to Intermediate Receiver, at the High Service Pumping Station, Clifton and 7th Avenues, Newark, N. J. PIERSON AND THEBERATH, '88, - - - - - 173

Review of Engine and Boilers of Steamboat "Rhode Island." WHITLOCK, '82, - - - - - - - - 86

Review of the Machinery of the Equitable Building, New York City, including Boilers, Engines, Heaters, Electric Lighting, etc. FOX AND HEISKELL, '86, - - - - - 156

*Van Nostrand's Magazine, 1878.

†*Transactions* American Society of Civil Engineers, 1881. Report of U. S. Board, Testing Iron and Steel, 1880.

‡*Journal* Franklin Institute, 1882.

VOL.

Review and Test of the Engines and Boilers of the Steamship "Knickerbocker," New York to New Orleans and Return. BEARD AND FIRESTONE, '87, - - - - - 168
Review of Boiler, Engines, and Pumps of Wilmington Water-Works. JENKINS AND MOELLER, '87, - - - - 164
Review of the Post & Sawyer Complete Combustion Boiler.* LOZANO, '87, - - - - - - - - -
Safety Boilers (Results of Trial to Determine Efficiency). BURHORN AND MCLEAN, '85, - - - - - - 144
Stationary Engine and Boiler Test (Experimental Determination of Efficiency). COFFEY AND FURMAN, '85, - - - 149
Steam Boiler Explosions (Theory and New Determination of Stored Energy). FOSTER AND TORRANCE, '84, - - - 112
Test of Engines and Boilers of Steamer "J. B. Williams," Pittsburg to Louisville. KERR AND WHIGHAM, '88, - - - 171
Testing of Boilers and Distribution of Power from Engines. DINKEL AND DUCOMMUN, '88, - - - - - 169
Test of Engines and Boilers of Steamship "Tallahassee." MILLER AND WILLIS, '88, - - - - - - - 173
Test of Babcock & Wilcox Boiler Connected with Roney Mechanical Stoker. FIELD, FIELDER, AND KELLOGG, '94, - - 194
Test of Babcock & Wilcox Boiler with Various Kinds of Coal. ANDERSON AND BURKE, '94, - - - - - 197
Test of Boilers and Engine of a Plant for the Manufacture of White Lead. RUPRECHT AND GNADE, '94, - - - 194
Test of Machines and Boilers of the Cincinnati Ice Manufacturing and Cold Storage Company's Plant. ANDERSON AND SHREVE, '88, - - - - - - - - 172
Test of Triple-Expansion Engines and Boilers of Ocean Tug "Plymouth." ANGELL AND JONES, '94, - - - -

BOILING POINT:

Determination of the Boiling Point of Nitro-Benzol. MANNING, '91, 179

BRAKES:

Continuous Railway Train Brakes. CRONISE, '81, - - - 77

BRIDGES:

Design of a Bridge Across the Hudson River at Poughkeepsie. RAPELJE, '77, - - - - - - - 32
A Bridge Design. DIXON, '81, - - - - - 71
Design of a New Suspension Foot Bridge. SANDT, '84, - - 127
Analysis of the P. R. R. Bridge over Newark Avenue, Jersey City. EVERHART, '86, - - - - - - - 159
Design for a Pratt Truss Railroad Bridge. FIELD, '86, - - 154
Design for a Railway Deck Bridge. ARNOLD, '86 - - - 159

**Journal* Franklin Institute, 1887.

VOL.

Design of a Railroad Bridge of 243 Feet Span Under Greatest and Least Loading, according to Practice of Present Day. COHEN AND CUNTZ, '92, - - - - - - - - 186
Design of a Truss Bridge. HARING, '83, - - - - - 97
Review of an Iron Draw Bridge. DILWORTH, '79, - - - 57
Review of Monongahela Bridge at Smithfield Street, Pittsburg, Pa. BUVINGER, '91, - - - - - - - 181
Review of Swing Bridge on N. Y. and Northern R. R. over Harlem River. W. W. JACKSON, '89, - - - - 191
The East River Bridge. HENNING, '76, - - - - 17

CABLE:

Comparison of the Cost of Running the Cable on the Elevated Road in Hoboken for Three Different Types of Engine Plants. RANDOLPH, '86, - - - - - - - - 162
Railroads. ELSON, '91, - - - - - - - - 182
Railroads. MAGEE, '88, - - - - - - - - 171
Railways (Construction and Costs). TUTTLE, '84, - - - 128
Suspension Cables of Brooklyn Bridge. HENNING, 76, - - 17
The Comparative Efficiency of Cable and Electric Systems as Determined from Tests on the Elevated Division of the North Hudson County Railway Company, Hoboken, N. J. WALL AND WOOD, '93, - - - - - - - - 188

CALORIMETER:

Determination of the Heat in Different Fuels by the Fischer's Calorimeter. VIDAL AND WAEFELAER, '91, - - - 180

CAM:

Cams (Systems and Kinetic Theory). VAN VLECK, '84, - - 137

CANAL:

Machinery Operating Canal Lock Gates. LEDERLE, '81, - - 70

CAR:

The Principles of Car Framing. WALL, '76, - - - 13

CELLULOSE:

Review of the Manufacture of Cellulose for a Fiber in Paper Making. COKER AND FERRIS, '88, - - - - 171

CEMENT:

The Latest Developments in the Mechanical Testing of Portland Cements. GOLDSMITH AND ROBERTS, '93, - - - 188

COAL:

Determination of the Heating Power of Coals by Means of the Mahler Calorimeter. DALE, INGLIS, PAULSEN, AND WILBOR, '93, 188
Determination of the Heat in Different Fuels by the Fischer's Calorimeter. VIDAL AND WAEFELAER, 91, - - - 180
Investigation of the Dodge Coal Storage System. CARLTON AND DE HART, '90, - - - - - - - 177

VOL.

On the Use of Waste Anthracite Coal. LUKENS, '85, - - 145

Test of Babcock & Wilcox Boiler with Various Kinds of Coal. ANDERSON AND BURKE, '94, - - - - - 197

COILS:

Transmission of Heat from Steam to Water through Coils of Iron Pipe. KOPP AND MEYSTRE, '93, - - - - - 190

COLD:

Comparison of Insulating Materials for Cold Storage. PARKER AND RIEGE, '93, - - - - - - - 187

COMPRESS:

The Machinery for Compressing Cotton. HALL, '87, - - 166

COMPRESSOR:

Compound Air Compressors. VAN ATTA, '81, - - - 78

Effect of a Perfect Spray Injection on the Efficiency of an Air Compressor. GAUSE AND POST, '91, - - - - 180

CONCRETE:

Experimental Tests of Concrete. EVERETT, '90, - - - 177

CONDENSERS:

Condensers for Steam Engines (Theory and Practice). BROADMEADOW AND WILLIS, '85, - - - - - - 147

CONSTRUCTION:

Mechanical Construction of the Organ. CHESTER, '86, - - 159

The Construction and Performance, as Determined by Trial of the Steamer "City of Fall River." ADGER AND SAGUE, '83, - 95

The Construction of Machine Shop Tools. GSANTNER, '78, - 41

CONVERTERS:

Lag of Electric Current Behind Potential for Westinghouse Converters. PALEN AND PLYER, '89, - - - - - 159

Tests of Efficiency of Westinghouse Converters. CUNTZ AND WAGNER, '87, - - - - - - - 167

COPPER:

On the Properties of Triple Alloys of Copper, Tin, and Zinc.* COSTER, '77, - - - - - - - - 30

Researches on the Triple Alloys: Copper, Zinc, and Tin.† JOBBINS, '82, - - - - - - - - 82

COTTON;

Cotton Pickers. DAWES, '79, - - - - - - 55

Design for a Mill for the Manufacture of Cotton Goods. IRWIN, '83, - - - - - - - - - 104

Steam Plant for Cotton Mill (an Original Design). GLASGOW AND RICE, '85, - - - - - - - - 151

**Transactions* American Society of Civil Engineers, 1881. Report of U. S. Board, Testing Iron and Steel, 1880.

†*Journal* Franklin Institute, 1882.

VOL.

The Machinery for Compressing Cotton. HALL, '87, - - 166

CREMATION:

Cremation of Garbage. BAYLESS AND MERKEL, '93, - -

CURRENT:

High Potentials With Alternating Currents. RITTENHOUSE, '93, 188

Test of a Westinghouse Alternating Current. ECHEVERRIA AND MULDAUR, '89, - - - - - - - 174

CYLINDER:

Test of a Pump to Determine Cylinder Condensation at Varying Speeds. MERRITT, '86, - - - - - - 161

DERRICK:

Design for a Fifty-Ton Floating Derrick. SORGE, '75, - - 6

DREDGING:

Design for a Dredging Machine. ZIMMERMANN, '76, - - 20

DYNAMIC:

An Investigation of the Dynamic Field by Means of a Revolving Coil. ATKINS AND SCHRAMME, '92, - - - - 186

DYNAMO:

An Application of Exploring Coil for Determining Disturbing Elements in a Dynamo. SMITH, PIERSON, '94, - - -

Efficiency Tests of Electric Generators Both as Dynamos and Motors. MOUNT AND NETTLETON, '91, - - - - 182

Experimental Determination of the Curves of E. M. F. of an Alternating Dynamo. HOFFMAN AND SEARING, '88, - - 170

Test of a Brush Dynamo. BANDARET AND BATES, '87, - - 164

Test of Dynamo and Engine in New York Athletic Club House. LORSCH AND MUSCHENHEIM, '91, - - - - - 183

The Characteristic Curves of a Westinghouse Alternating Dynamo. REEVE, '88, - - - - - - 170

Theoretical Dynamo Design. FARRAR AND HINKLE, '90, - - 178

DYNAMOMETER:

Dynamometers (Experimental Investigation). BENSEL AND BUSH, '84, - - - - - - - - - 136

ECCENTRIC:

Eccentric and Valve of Steam Engines (Comparison of Existing Types). THOMAS, '84, - - - - - - 123

ELECTRIC:

Comparative Test of Electric Car Motors. HARTPENCE, KLUMPP, AND MCGOWAN, 94, - - - - - - - -

Comparison of Electric Light Plant Driven by Water Power or by Steam. KENNEDY, KNOX, AND SMITH, '91, - - - 182

Descriptive Tests of Two Armington & Sims Engines for Electric Lighting at Ward's Island. LEONHARD AND LEWIS, '93, - 187

VOL.

Design of an Electric Arc Lighting Plant. GIBERGA, '86, - - 158
Determination of Efficiency of a New Daft Electric Motor. BONNETT AND HILL, '89, - - - - - - 174
Economy of Electric Lighting by Incandescence. HOWELL, '81, - 72
Electric Motors. CAMPBELL AND MCLEAN, '88, - - - 170
Electric Motors. BAYLES AND SERRELL, '87, - - - - 167
Electric Motors: Commercial Economy of Systems. CORWIN, '85, 152
Electric Railways. BIRDSALL, '86, - - - - - - 155
Lag of Electric Current Behind Potential for Westinghouse Converters. PALEN AND PLYER, '89, - - - - - 189
Photometric Comparisons of High Power Gas Burners and Electric Lamps. HALL AND VAN DER WILLIGEN, '88, - - 169
Review and Test of the Multiple Distribution System of an Electric Railway on Coney Island at Brighton Beach. FERNANDEZ, HAKE, AND HARRISON, '92, - - - - 185
Review of Dover Electric Light Plant. DAVIS AND DE GRESS, '91, 184
Review of Edison Electric Light Plant's Three-Wire System. KISSAM AND SMITH, '90, - - - - - - 177
Review of Electric Railway, Richmond, Va. PRENTISS AND SCOTT, '89, - - - - - - - - 174
Review of the Brooklyn and Coney Island Electric Railway. HANSEN AND HOLBERTON, '91, - - - - - 183
Review of the Leonard System of Operating Electric Motors. GARDINER, JACKSON, AND JONES, '92, - - - - 185
Temperature of Wires Carrying Electric Currents. GRISWOLD, '88, 170
Test of an Electric Light Plant, Stokes Building, New York City. BOODY AND CUNTZ, '93, - - - - - - 188
Test of an Electric Motor and Other Machinery for an Underground Railroad for a Mining Plant at Forest City, Pa. HUPPERTZ AND WILKES, '93, - - - - - 187
Test of Bergen and Jersey City Electric R. R. ADAMS AND HUNTER, '93, - - - - - - - - 188
Test of Crocker-Wheeler Electric Motor. TODD AND TORRANCE, '90, - - - - - - - - - 178
Test of an Electric Railway Power Station at West Haven, Conn. COLLES AND GALLAHER, '94, - - - - -
Test of Electric Light Plant at the D. L. & W. R. R. Station at Hoboken. LAW AND LITCHFIELD, '92, - - - - 185
Test of Efficiency of an Electric Motor. STEVENS AND WREAKS, '90, 178
Test of Electric Light Plant, Madison, N. J. BRUEN AND BROOKFIELD, '93, - - - - - - - - 188
Test of Electric Plant of the Newark Passenger Railroad. SPENCER AND SUMMERS, '91, - - - - - 184
Test of the Electric Light Plant at Bloomingdale Company's Store. COLEMAN, COX, AND FRIDENBERG, '94, - - - - 195

VOL.

Test of the Electric Light Plant at the N. J. C. R. R. Station, Jersey City. GURNEY, HOTOPP, SHEPARD, '92, - - - 185
Test of the Incandescent Electric Light Plant of the "Navarro" Apartments, New York City. DOW AND OELBERMANN, '91, - 182
The Comparative Efficiency of Cable and Electric Systems as Determined from Tests on the Elevated Division of the North Hudson County Railway Company, Hoboken, N. J. WALL AND WOOD, '93, - - - - - - - - 188
The Economy of Electric Lighting by Incandescence. HOWELL, '81, - - - - - - - - - 72
Theoretical Comparison of Thomson and Edison Systems for 1,000 Electric Lights. JOUBERT, '91, - - - - - 183

ELECTRICAL:

An Experimental Determination of the Electrical Resistance of Twelve Different Liquids. LOWENHERZ AND WHITNEY, '92, 185
Efficiency Test of Electrical Generators Both as Dynamos and Motors. MOUNT AND NETTLETON, '91, - - - - 182
Efficiency Tests of Thomson & Houston Series Electrical Machines, NORCROSS AND SANBORN, '91, - - - - - 183
Electrical Horse-Power Consumed by a Motor Car Under Varying Conditions, Newark, N. J. FURMAN AND SLOCUM, '93, - - 188
Electrical Transmission of Power. GIBBS, '82, - - - 83
Electrical Welding. REED AND UHLENHAUT, '88, - - - 169
The Measure of High Temperatures by the Electrical Resistance of Platinum, Including a Design for an Electrical Pyrometer. EBSEN AND FRAZER, '90, - - - - - - 177

ELECTRICITY:

Electricity as a Motive Power on Tramways. PARKER, '84, - 132
The Storage of Electricity. ALDEN, '84, - - - - 131
Transmission of Energy by Electricity. MCCOY, '85, - - 149

ELECTRO:

Experiments in the Field of E. M. F. of Armature of Dynamo Electrical Machines. BIRDSALL, '86, - - - - 155

ELEVATOR:

Design for a Stationary Grain Elevator. SHELDON, '78, - - 43
Design for a Telescopic Hydraulic Elevator. BRINCKERHOFF, '77, 29
Elevator Machinery, Construction and Operation. DREYSPRING, '85, 141
Elevators, Otis, Test of. MERRICK, VOGELIUS, AND WETTLAUFER, '92, 190

ENERGY:

Transmission of Energy by Electricity. MCCOY, '85, - - 149

ENGINE:

Aero Steam Engines and Their Utilization of the Total Heat of Combustion.* HENDERSON, '73, - - - - - - 1

**Journal* Franklin Institute, 1873.

VOL.

Analytical Study of a Straight Line Engine. DARBY AND SMITH, '91, 184
A New Double-Acting Gas Engine (Original Design and New Invention). BRISTOL, '84, - - - - - - - 134
An Experimental Determination of the Efficiency of an Otto Gas Engine.* BROOKS AND STEWARD, '83, - - - - 105
A Theoretical Investigation of Vapor Engines. MENDOZA AND WESTCOTT, '90, - - - - - - - - 178
Automatic Engines: Practice and Theory (Experimental Determination). ALDRICH AND MITCHELL, '84, - - - - 130
Boiler and Engine Test. FISCHER, '85, - - - - 150
Comparative Test of Slide Valve Engine and a Corliss Engine. LAWTON AND CAMERON, '94, - - - - - 193
Comparison of Single and Compound Engines. ROOD, '82, - 88
Compound Engine and Water-Wheel Tests (Determination of Power Required for Running Saw Mills). MARTINEZ, '85, - 141
Compounding of a Beam Engine (Original Design). CARROLL, '84, 126
Condensers for Steam Engines (Theory and Practice). BROADMEADOW AND WILLIS, '85, - - - - - - - 147
Descriptive Tests of Two Armington & Sims Engines. LEONHARD AND LEWIS, '93, - - - - - - 187
Design for a High-Speed Vertical Steam Engine. BRISTOL AND CHANDLER, '93, - - - - - - - - 188
Design for a 10 Horse-Power Steam Engine. ANTZ, '78, - - 48
Design of a Compound Launch Engine. THOMAS, '86, - - 162
Determination of Speed and Efficiency of Engines of the Steamers "Pomham" and "Squantum." PHELPS AND WILDMAN, '90, 176
Determination of Water Consumption of Ball & Wood Engine Under Light Loads. COOK AND LORD, '93, - - - 188
Discussion of Cut-off Valve Gears for the Corliss Engine. SLACK, '86, - - - - - - - - - - 162
Eccentric and Valve of Steam Engine (Comparison of Existing Types). THOMAS, '84, - - - - - - 123
Energy and the Steam Engines (Traces Energy Passing Through Boiler and Engine). WURTZ, '84, - - - - 109
Ericsson's Hot-Air Engine. WILLIAMS, '81, - - - 76
Experimental Investigation of the Korting Gas Engine. BANG AND STUECK, '88, - - - - - - - - 170
Friction of Single and Compound Engines. PIERCE, '84, - - 125
Modern American Steam Fire Engines. ROBBINS, '79, - - 53
On the Most Economical Range of Power Obtainable from a Given Steam Engine. PRACY, '81, - - - - 79
Pumping Engine for City Water Supply. BUTLER, '82, - - 84
Review and Experimental Test of the Burnham Automatic Engine. LA POINTE AND LILLY, '86, - - - - - 161

* Van Nostrand's Magazine, 1883.

VOL.

Review and Test of Engines and Boilers of Steamship "Knickerbocker," New York to New Orleans and Return. BEARD AND FIRESTONE, '87, - - - - - - - - 168
Review of Boiler, Engine, and Pumps of the Wilmington Water-Works. JENKINS AND MOELLER, '87, - - - - 164
Review of Crist Vibrating Compound Engine. EASTWOOD AND WYANT, '89, - - - - - - - - - 174
Review of Engine and Boilers of Steamboat "Rhode Island." WHITLOCK, '82, - - - - - - - - 86
Review of Engines of P. R. R. Tugboat "Blue Bonnet." MCELROY AND PARSONS, '87, - - - - - - - 164
Review of Engines of P. R. R. Tugboat "Delaware." DILWORTH AND MACHOLD, '85, - - - - - - - - 139
Review of Engines of Steamer "Mary Powell." WALLIS, '79, - 58
Review of Engines of Steam Tug "W. E. Cheney." AIKIN, '79, 56
Review of Furnace Blowing Engine. BOYER, '90, - - - - 178
Review of Naphtha Engine. BEYER AND DOTY, '88, - - 173
Review of Pumping Engines. CREMER, '76, - - - 14
Review of the Mechanism in the Equitable Building, New York City, Including Boilers, Engines, Heaters, Electric Lights, etc. FOX AND HEISKELL, '86, - - - - - 156
Review of Watts, Campbell & Co.'s Corliss Engines. NORRIS, '85, 148
Stationary Engine and Boiler Test (Experimental Determination of Efficiency). COFFEY AND FURMAN, '85, - - - 149
Steam Engine Efficiency (Separate Determination of Wastes and Law of Their Variation). GATELY AND KLETZSCH, '84, - 122
Steam Engine Efficiency. WADE, '85, - - - - - 150
Steam, Ether, and Other Vapors as Working Substances in Heat Engines (Original Calculation of Efficiency). GANTT AND MAURY, '84, - - - - - - - - - 118
Testing of Boilers and Distribution of Power from Engines. DINKEL AND DUCOMMUN, '88, - - - - - - 169
Test of Boilers and Engine of a Plant for the Manufacture of White Lead. RUPRECHT AND GNADE, '94, - - - - 194
Test of Dynamo and Engine in New York Athletic Club House. LORSCH AND MUSCHENHEIM, '91, - - - - - - 183
Test of Engines and Boilers of Steamship "J. B. Williams," Pittsburg to Louisville. KERR AND WHIGHAM, '88, - - - 171
Test of Engines and Boilers of Steamship "Tallahassee." MILLER AND WILLIS, '88, - - - - - - - - - 173
Test of Otto Gas Engines Operating an Electric Plant with Producer Gas, Danbury, Conn. BRAINE, MACDONALD AND MERRITT, '93, - 188
Test of Triple-Expansion Engines and Boilers of Ocean Tug "Plymouth." ANGELL AND JONES, '94, - - - - -
Test of Two Small Engines in Shop of Institute Joined to Work as Compound Engine. HAMILTON AND HOXIE, '89, - - 174

VOL.

Test of Water Consumption of Rollins Engine Under Light Loads. GILMORE AND MACCORD, '94, - - - - - 196
The American Beam Engine. WALLIS, '76, - - - - 25
The Armington & Sims Engine (Construction and Theory). TUCKER, '84, - - - - - - - - 124
The Commercial Efficiency of Steam Engines. WRIGHT, '83, - 85
The Compound Engine. IDELL, '77, - - - - - 35
The Gerner Marine Engine. GERNER, '78, - - - - 51
The Marine Engine. DASHIELL, '79, - - - - - 61
Water Consumption of a 50 Horse-Power Ball & Wood Engine. CORBIN, '94, - - - - - - - - -

FILTRATION:
Water Filtration by Mechanical Methods. EMMET AND PEARCE, '91, 182

FIRE:
Apparatus for Extinguishing Fires. VAIL, '76, - - - 18
Fireproof Materials. RENWICK, '85, - - - - - 143
Modern American Steam Fire Engines. ROBBINS, '79, - - 53

FLIGHT:
Artificial Flight, DOW, '76, - - - - - - 12

FORGE:
Design for a Catalan Forge. MYERS, '78, - - - 49

FOUNDRY:
Design for an Iron Foundry. RAQUÉ, '76, - - - - 26

FRAMING:
The Principles of Car Framing. WALL, '76, - - - 13

FUEL:
An Experimental Determination of the Efficiency of Tan for Fuel at Procter's Tannery, Jameson City, Pa. MURRAY, '92, 185
Gas Fuel in Engineering. MCNAUGHTON, '83, - - - 93
Liquid Fuels. BEATTY, '84, - - - - - - 108
Peat as a Fuel. SUYDAM, '78, - - - - - - 52
Determination of the Heat in Different Fuels by the Fischer Calorimeter. VIDAL AND WAEFELAER, '91, - - - - 180

FURNACE:
Investigation of the Efficiency and Temperature of a Reverberatory Furnace. KURSHEEDT, '80, - - - - - 66
Project for the Erection of Two Blast Furnaces.* KENT, '76, - 11
Review of a Blast Furnace at Bethlehem Iron Works. BEERS AND DANZIGER, '89, - - - - - - - 174
Review of a Furnace Blowing Engine. BOYER, '90, - - 178

GALVANIC:
Determination of Constants of Galvanic Elements. HEGER, '79, 64

**Iron Age*, 1876.

VOL.

GARBAGE:

Cremation of. BAYLESS AND MERKEL, '93. - - - -

GAS:

A New Double-Acting Gas Engine (Original Design and New Invention). BRISTOL, '84, - - - - - - 134

An Experimental Determination of the Efficiency of an Otto Gas Engine. BROOKS AND STEWARD, '83, - - - 105

Experimental Investigation of the Korting Gas Engine. BANG AND STUECK, '88, - - - - - - - 170

Gas Fuel in Engineering. MCNAUGHTON, '83, - - - 93

Photometric Comparisons of High Power Gas Burners and Electric Lamps. HALL AND VAN DER WILLIGEN, '88, - - - 169

Stresses and Strains in Gas Holder Framework. COTTIER AND ELLSWORTH, '94, - - - - - - - -

Test of Otto Gas Engines Operating an Electric Light Plant with Producer Gas, Danbury, Conn. BRAINE, MACDONALD, AND MERRITT, '93, - - - - - - - 188

The Manufacture of Coal Illuminating Gas. TRAUTWEIN, '76, - 21

Water Gas Compared with Coal Gas. HUMPHREYS, '81, - - 68

GATES:

Machinery for Operating Canal Lock Gates. LEDERLE, '81, - 70

GEARING:

On Hook's Helical Gearing and a Machine for Making It. THOMPSON, '78, - - - - - - - - - 38

GOVERNOR:

Analysis of the Ball Engine Governor. THUMAN AND TWITCHELL, '90, - - - - - - - - - 178

Analytical Investigation of the Buckeye Governor. WILLIS AND WORTENDYKE, '89, - - - - - - - 174

Experimental Determination of Efficiency of Centrifugal Governors. SMITH, '85, - - - - - - - 142

Theory and Construction of Governors for Prime Movers. PRATT AND WILLIAMS, '85, - - - - - - - 138

HAMMER:

Design for a 15-Ton Steam Hammer. WILES, '76, - - - 19

HARVESTING:

Harvesting Machines.* UEHLING, '77, - - - - 33

HEAT:

Determination of the Heat in Different Fuels by the Fischer Calorimeter. VIDAL AND WAEFELAER, '91, - - - - 180

Steam, Ether, and Other Vapors as Working Substances in Heat Engines (Original Calculation of Efficiency). GANTT AND MAURY, '84, - - - - - - - - 118

* *Iron Age*, 1877.

VOL.

Transmission of Heat from Steam to Water through Coils of Iron Pipe. KOPP AND MEYSTRE, '93, - - - - - - 190

HEATERS:

Review of Mechanism in Equitable Building, New York City, Including Boilers, Engines, Heaters, Electric Lighting, etc. FOX AND HEISKELL, '86, - - - - - - 156

HEATING:

Determination of the Heating Powers of Coals by Means of the Mahler Calorimeter. DALE, INGLIS, PAULSEN, AND WILBOR, '93, 188

Heating and Ventilating. MAGEE, '83, - - - - - 92

Heating and Ventilation of the New York Post-Office. FEZANDIÉ, '75, - - - - - - - - - - - 7

Heating and Ventilation of Symes Theater. MEYER AND WHITCOMB, '92, - - - - - - - - - 190

HOISTING:

Hoisting Machinery (Review of Apparatus for a Deep Shaft). WHITNEY, '89, - - - - - - - - - 111

ICE:

Mechanical Refrigerating Machines (Theory and Experimental Determination of Efficiency). JACOBUS AND RENWICK, '84, - 117

Hygeia Ice Plant, Test of. GRISWOLD, HUPFEL, AND MCKENZIE, '93, 192

Test of a De la Vergne Refrigerating Machine. PULSFORD, ROSENBUSCH, AND SHOEMAKER, '94, - - - - - 194

Test of Ammonia Compression Ice Machine. ANDERSON AND PAGE, '87, - - - - - - - - - 165

Test of a Pontifex Refrigerating Machine. GRAF AND WHITNEY, '90, - - - - - - - - - 177

Test of Machines and Boilers of Cincinnati Ice Manufacturing and Cold Storage Company's Plant. ANDERSON AND SHREVE, '88. - - - - - - - - - - 172

Test of Refrigerating Plant of the Hodges & Havenstrite System. AXFORD AND WEEKS, '93, - - - - - - 191

ILLUMINATION:

Petroleum Illumination. KING, '86, - - - - - 160

INCANDESCENCE:

The Economy of Electric Lighting by Incandescence. HOWELL, '81, - - - - - - - - - - 72

Test of the Incandescent Electric Light Plant of the "Navarro" Apartments, New York City. DOW AND OELBERMANN, '91, - 182

INDICATOR:

Construction and Use of the Steam Indicator. STERN, '82, - 89

INJECTOR:

Steam Injectors. LADD, '81, - - - - - - - 74

The Theory of Steam Injectors (Experimental Investigation and Revision of Theory). BARNES AND FEARN, '84, - - - 133

VOL.

INSULATION:
Comparison of Insulating Materials for Cold Storage. PARKER AND RIEGE, '93, - - - - - - - - 187
Effect of Moisture on the Insulation of Wire. DE LA ROSA, '91, 179

IRON:
Design for an Iron Foundry. RAQUÉ, '76, - - - - 26
Design for an Iron Roll Mill. COOKE, '79, - - - - 65
Experimental Determination of the Magnetic Properties of Mitis Iron. HARVEY, '90, - - - - - - - - 178
Experimental Determination of the Strength of Malleable Cast Iron. COOK, '86, - - - - - - - - 159
Experiments on Triangular Cast-Iron Beams. PERKINS, '91, - 179

JUTE:
Jute Manufacture and Machinery. LYALL, '84, - - - 113

LAMP:
Test of a Westinghouse Alternating Arc Lamp. BRINCKERHOFF AND HAWORTH, '90, - - - - - - - - 177
The Resistance of Incandescent Lamps at High E. M. F. FLACK, '87, 164

LAUNCH:
Design and Specification for a Steam Launch. MOWTON, '86, - 161
Design of a Compound Launch Engine. THOMAS, '86, - - 162
The Machinery of Swift Steam Launches. GIBBS, '78, - - 40

LATHE:
A New Design for a Turret Lathe. RICHARDSON, '89, - - 176

LIGHTHOUSE:
Lenticular Illuminating Apparatus for Lighthouses. BONN, '78, - 42

LIME:
Review of a Plant for the Manufacture of Wood Spirit and Acetate of Lime at Galeton, Pa. CORBETT AND WELLS, '92, - - 185

LINK:
Comparison of the Ball Automatic Cut-off Gear and Stephenson Link Motion. JONES, '90, - - - - - - 176
Locomotive Link Motions. RIDDLE, '81, - - - - 75
The Joy Valve Gear *versus* the Stephenson Link Motion. HENDERSON, '83, - - - - - - - - - 106

LOCOMOTIVE:
Report on Trial of Locomotive No. 169, C. R. R. of N. J.* ABBEY AND BALDWIN, '85, - - - - - - - -
Comparative Tests of Compound and Simple Locomotives on N. J. C. R. R. KENYON, MATHEY, AND TAYLOR, '94, - -
Development of Smoke-Boxes of Locomotives. FIELD AND WALLIS, '91, - - - - - - - - 184
Development of the Locomotive. FOSTER, '84, - - - 119

* *Engineering*, London, September, 1885.

VOL.

Disturbing Forces in the Locomotive. WHITE, '79, - - 54
Fast Locomotives. ROPES, '83, - - - - - 102
Leading Points in Locomotive Construction and Performance. RUSBY AND STEVENS, '85, - - - - - - 146
Locomotive Equipment of English Railways. SMITH, '89, - 175
Locomotive Construction. CAMPBELL, '88 - - - - 170
Locomotive Link Motions. RIDDLE, '81, - - - - 75
Stability of Locomotives (Mathematical Investigation). CARROLL, '84, - - - - - - - - - 121
Test of Locomotive No. 171, C. R. R. of N. J. WOLFF AND WYNKOOP, '88, - - - - - - - - 173
The American Locomotive Engine (Theory and Current Practice). DENT, '84, - - - - - - - - - 135
The Locomotive Engine. COOKE, '82, - - - - - 81
Theory of the Tractive Power of Locomotives. DENTON, '75, - 5
A New Locomotive Valve Gear and System of Compounding. CONNET, '89, - - - - - - - - - 197

LUBRICATION:
Materials and Apparatus of Lubrication. CARTWRIGHT, '82, - 91

MACHINE:
Arrangement and Superintendence of Machine Shops. WILKES, '85, 140
Design for a Dredging Machine. ZIMMERMANN, '76, - - 20
Design of Machinery for a Sugar Refinery. KOEZLY, '75, - - 8
Efficiency Tests of Thomson & Houston Series Machines. NORCROSS AND SANBORN, '91, - - - - - - 183
Elevator Machinery Construction and Operation. DREYSPRING, '85, - - - - - - - - - 141
General Plans and Estimates on Machine Shops for the Construction of Marine and Stationary Engines. POST, '74, - - 2
Harvesting Machines. UEHLING, '77, - - - - 33
Hoisting Machinery (Review of Apparatus for a Deep Shaft). WHITING, '84, - - - - - - - - 111
Jute Manufacture and Machinery. LYALL, '84, - - - 113
Machinery Operating Canal Lock Gates. LEDERLE, '81, - - 70
Mechanical Refrigerating Machines (Theory and Experimental Determination of Efficiency). JACOBUS AND RENWICK, '84, - 117
Method of Testing the Accuracy of Machinery. HAZARD, '78, - 45
Mowing Machinery (Including Experimental Determination of Resistance). ADRIANCE, '85, - - - - - 153
On Hook's Helical Gearing and a Machine for Making It. THOMPSON, '78, - - - - - - - - - 38
Paper Machinery. KINGSLAND, '79, - - - - - 60
Review of a Taber Moulding Machine. MOORE, '90, - - 177
Review of the Machinery of the Towboat "Coal City." DRUMMOND AND SMITH, '88, - - - - - - 172

VOL.

Steam Pumping Machinery. BRAINARD AND MACKIEWICZ, '84, - 129
Test of a De la Vergne Refrigerating Machine. ANDERSON AND PAGE, '87, - - - - - - - - - 165
Test of Ammonia Compression Ice Machine. PULSFORD, ROSENBUSCH, AND SHOEMAKER, '94, - - - - - 194
Test of a Pontifex Refrigerating Machine. GRAF AND WHITNEY, '90, - - - - - - - - - - 177
Test of Machines and Boilers of the Cincinnati Ice Manufacturing and Cold Storage Company's Plant. ANDERSON AND SHREVE, '88, - - - - - - - - - - 172
The Machinery for Compressing Cotton. HALL, '87, - - 166

MAGNET:

Experimental Determination of the Magnetic Properties of Mittis Iron. HARVEY, '90, - - - - - - 178
Exploration and Mapping of the Field of Electro-Magnets by Means of a Revolving Coil. TRAUTVETTER, '90, - - 179

MILL:

Compound Engine and Water Wheel Tests (Determination of Power Required for Running Saw Mills). MARTINEZ, '85, 141
Design for a Mill for the Manufacture of Cotton Goods. IRWIN, '83, 104
Design for a Mill for the Manufacture of Merchant Iron. COOKE, '79, - - - - - - - - - - 65
Design for a Paper Mill. KINGSLAND, '76, - - - - 16
Steam Plant for Cotton Mill. (An Original Design.) GLASGOW AND RICE, '85, - - - - - - - - 151

MILLING:

Milling and Its Machinery. PLAISTED, '83, - - - - 96

MOTOR:

Determination of the Efficiency of a New Daft Electric Motor. BONNETT AND HILL, '89, - - - - - - 174
Electric Motors. CAMPBELL AND MCLEAN, '88, - - - 170
Electrical Horse-Power Consumed by a Motor Car under Varying Conditions, Newark, N. J. FURMAN AND SLOCUM, '93, - 188
Electrical Motors: Commercial Economy of Systems. CORWIN, '85, 152
Review of the Leonard System of Operating Electric Motors. GARDINER, JACKSON, AND JONES, '92, - - - - - 185
Test of a Crocker-Wheeler Electric Motor. TODD AND TORRANCE, '90, - - - - - - - - - - 178
Test of an Electric Motor and Other Machinery for an Underground Railroad for a Mining Plant at Forest City, Pa. HUPPERTZ AED WILKES, '93, - - - - - - 187
Test of Efficiency of an Alternating Motor. STEVENS AND WREAKS, '90, - - - - - - - - 178
Wind Motors. FRAENTZEL, '83, - - - - - - 103

VOL.

NAPHTHA:
Review of a Naphtha Engine. BEYER AND DOTY, '88. - - 173

NITRO-BENZOL:
Determination of the Boiling Point of Nitro-Benzol. MANNING, '91, 179

OIL:
Manufacture of Cotton Seed Oil. WHEATLEY, 87, - - - 167
The Manufacture of Cotton Seed Oil. TAYLOR, '88, - - 171

ORES:
Mechanical Separation of Ores. PFORDTE, '86, - - - 162

ORGAN:
The Mechanical Construction of the Organ. CHESTER, '86, - 159

PAPER:
Paper Machinery. KINGSLAND, '79, - - - - - 60
Paper Manufacture. SMITH, '79, - - - - - 59
Review of the Manufacture of Cellulose for a Fiber in Paper Making. COKER AND FERRIS, '88, - - - - 171

PEAT:
Peat as a Fuel. SUYDAM, '78, - - - - - - 52

PETROLEUM:
Petroleum Illumination. KING, '86, - - - - - 160

PIPE:
General Manufacture of Iron Pipe. QUIMBY, '87, - - - 168

PLATINUM:
The Measurement of High Temperatures by the Electrical Resistance of Platinum, Including a New Design for an Electrical Pyrometer. EBSEN AND FRASER, '90, - - - - 177

POWER:
Comparison of Electric Light Plant Driven by Water Power or by Steam. KENNEDY, KNOX, AND SMITH, '91, - - - 182
Determination of Power to Drive Machinery for Turning New London Bridge. BOLLER AND SCHUMACHER, '91, - - 179
Electrical Transmission of Power. GIBBS, '82, - - - 83
Manufacture of Cane Sugar (Experimental Determination of Power). MORRIS AND RAE, '84, - - - - - 120
On the Most Economical Range of Power Obtainable from a Given Steam Engine. PRACY, '81, - - - - - 79
Test of Boilers and Distribution of Power from Engines. DINKEL AND DUCOMMUN, '88, - - - - - - 169
The Distribution of Power in the Waddell-Entz Storage Battery System, 2d Avenue, New York City. GIBSON, LOZIER, AND OPPERMANN, '94, - - - - - - - 193
Theory of the Tractive Power of Locomotives. DENTON, '75, - 5
Transmission of Power by Compressed Air. ZAHNER, '78, - 39
Transmission of Power by Wire Ropes. STAHL, '76, - - 22

VOL.

Water and Steam as Motive Powers. WETZLER, '82, - - 90

PRESSURE:

Apparatus for Measuring Fluid Pressures. HICKOK, '83, - - 100

PRINTING PRESS:

Design of a Flat Bed Printing Press. DEAR AND SEEMAN, '93, - 192

PROPELLER:

The Screw Propeller.* WARRINGTON, '83, - - - - 94

The Screw Propeller: Principles and Practice. RIESENBERGER, '76, 23

PULSOMETER:

Efficiency Test of the New Pulsometer. ATWATER AND HODGES, '91, - - - - - - - - - - 183

PUMPS:

Direct-Acting Steam Pumps. ROBERTS, '77, - - - 28

Experimental Test of Worthington Pump and Boiler at High Service Pumping Station, 99th Street and 9th Avenue, New York City. METCALFE, MORTON, AND WHITE, '86, - - - 161

Test of Worthington Pumps and Boilers with Special Reference to Intermediate Receiver at High Service Pumping Station, Clifton and 7th Avenue, Newark, N. J. PIERSON AND THEBERATH, '88, - - - - - - - - - 173

On Centrifugal Pumps. BREWER, '76, - - - - 15

Pumping Engine for City Water Supply. BUTLER, '82, - - 84

Review of Boiler, Engine, and Pumps of Wilmington Water-Works. JENKINS AND MOLLER, '87, - - - - 164

Review of Pumping Engines. CREMER, '76, - - - 14

Report on Test of Pumping Plant. EDWARD AND WILLIAM MUNKWITZ, '85, - - - - - - - - 153

Steam Pumping Machinery. BRAINARD AND MACKIEWICZ, '84, - 129

Test of a Davidson Direct-Acting Steam Pump. CRISFIELD, '87, 164

Test of a Pump to Determine Cylinder Condensation at Varying Speeds. MERRITT, '86, - - - - - - 161

Test of a Worthington High-Duty Pump, Hackensack Water-Works. DEMAREST AND YEARANCE, '88, - - - - 171

RADIATION:

Experimental Determination of Absolute Radiation. MAYER, '89, 174

RAIL:

A Comparative Review of the Prominent Eastern Bessemer Steel Rail Works. COX AND DIX, '87, - - - - - 165

RAILROAD:

Cable Railroads. ELSON, '91, - - - - - - 182

Cable Railroads. MAGEE, '88, - - - - - - 171

Cable Railways (Construction and Costs). TUTTLE, '84, - - 132

**Journal* Franklin Institute, 1884.

VOL.

Continuous Railway Train Brakes. CRONISE, '81, - - - 77
Electric Railways. BIRDSALL, '86, - - - - - 155
Railway Signaling. LONGSTREET, '79, - - - - 63
Resistance of Railway Trains. RANDOLPH, '83, - - - 99
Review of Brooklyn and Coney Island Electric Railway. HANSEN AND HOLBERTON, '91, - - - - - - 183
Review of Electric Railway, Richmond, Va. PRENTISS AND SCOTT, '89, - - - - - - - - - 174
Test of an Electric Railway Power Station at West Haven, Conn. COLLES AND GALLAHER, '94, - - - - - 191
Test of Bergen and Jersey City Electric Railroad. ADAMS AND HUNTER, '93, - - - - - - - - 188
The Metropolitan Elevated R. R. RAMIREZ, '79, - - - 62

REFRIGERATION:

Mechanical Refrigerating Machines (Theory and Experimental Determination of Efficiency). JACOBUS AND RENWICK, '84, - 117
Hygeia Ice Plant, Test of. GRISWOLD, HUPFEL, AND MCKENZIE, '93, 192
Test of a De la Vergne Refrigerating Machine. PULSFORD, ROSENBUSCH, AND SHOEMAKER, '94, - - - - - 194
Test of Ammonia Compression Ice Machine. ANDERSON AND PAGE, '87, - - - - - - - - - 165
Test of a Pontifex Refrigerating Machine. GRAF AND WHITNEY, '90, - - - - - - - - - 177
Test of Machines and Boilers of Cincinnati Ice Manufacturing and Cold Storage Company's Plant. ANDERSON AND SHREVE, '88, - - - - - - - - - - 172
Test of Refrigerating Plant of the Hodges & Havenstrite System. AXFORD AND WEEKS, '93, - - - - - - 191

RUBBER:

Vulcanized Rubber. SCHLESINGER, '87, - - - - 168

SHIP:

Ship Propulsion. DASHIELL, '79, - - - - - 61
Systematic Method of Ship Design (Theory of New System). PARSONS, '84, - - - - - - - 114
The Engineering of an Internal Ship Basin (Original Design). CLERK, '85, - - - - - - - - - 140

SHOP:

Arrangement and Superintendence of Machine Shops. WILKES, '85, - - - - - - - - - 140
General Plans and Estimates on Machine Shops for Construction of Marine and Stationary Engines. POST, '74, - - - 2

SHOVEL:

Rotary Steam Snow Shovel. ACKERMAN AND CARLL, '91, - 179

VOL.

SIGNAL:
Railway Signaling. LONGSTREET, '79, - - - - 63

SILK:
Plans for an American Silk Factory. VAN WINKLE, '77 - - 34

SMOKE:
Development of Smoke-Boxes of Locomotives. FIELD AND WALLIS, '91, - - - - - - - - 184

SPECULA:
Figuring Specula. STEPHENS, '78, - - - - - 47

SPRINGS:
The Theory and Manufacture of Springs.* DE BONNEVILLE, '78, 50

STEAM:
Comparison of an Electric Light Plant Driven by Water Power or by Steam. KENNEDY, KNOX, AND SMITH, '91, - - 182
Estimates and Possible Improvements in Economy in the Steam Plant of a Woolen Mill. LOUD AND TRUBE, '90, - - 178
Improvement in the Use of Steam. TATHAM, '81, - - - 69
Review and Experimental Test of the Steam Plant of the Steamship "Iroquois." KING, POWELL, AND SCHIEBLER, '92, - - 186
Saturated Steam. DAWSON, '88, - - - - - 169
Some Mechanical Properties of Vapors, Especially of Steam. ERDMAN AND WALKER, '91, - - - - - 180
Steam, Ether, and Other Vapors as Working Substances in Heat Engine. GANTT AND MAURY, '84, - - - - 118
Test of a Steam Plant. HILLER, '89, - - - - - 176
Test of Steam Plant of the New York Cotton Exchange. KIERNAN AND MILLER, '87, - - - - - - - 168

STEAMER:
Design for a Side-Wheel Steamer. NASH, '77, - - - 27
Design for Hull of a Steel Steamer for Merchant Marine for 15 Knots per Hour. DOUGLAS AND FANNING, '93, - - - 188
Determination of Speed and Efficiency of Engines of Steamers "Pomham" and "Squantum." PHELPS AND WILDMAN, '90, - 176
Performance of the Steamboat "Rhode Island." WEBSTER, '82, - 87
Review of a Whaleback Steamer and Test of Steam Plant on Same. POST AND STRONG, '92, - - - - - 186
Review of Whaleback Steamer "Knickerbocker," New York to New Orleans and Return. BEARD AND FIRESTONE, '87, - 168
Review of Steamer "Mary Powell." WALLIS, '79, - - - 58
Test of a Double-Screw Ferryboat "Bremen" in Ferry Service. HILL, LUDLOW, AND MILLER, '92, - - - - - 186
Test of Engines and Boilers of Steamer "J. B. Williams," Pittsburg to Louisville. KERR AND WHIGHAM, '88, - - 171

* Van Nostrand's Magazine, 1878.

VOL.

Test of Engines and Boilers of Steamer "Tallahassee." MILLER AND WILLIS, '88, - - - - - - - - 173
The Construction and Performance, as Determined by Trial, of the Steamer "City of Fall River."* ADGER AND SAGUE, '83, - 95

STEEL:
Chrome Steel. HART AND CALISCH, '87. - - - - 165
Clapp-Griffith Steel. FULLER AND LOPEZ, '88. - - - 172
Electro-Magnetization of Nickel Steel. BUFFETT, '94. - -
Improvements in the Bessemer Process. DAWES, '83, - - 107
On the Strength of Steel.† BAIRD, '78, - - - - 36
Project for the Erection of a Bessemer Steel Plant. PIERCE, '77, - 31
Review of the Prominent Eastern Bessemer Steel Rail Works. COX AND DIX, '87, - - - - - - - - 165

STOKER:
Test of Roney's Mechanical Stoker. FIELD, FIELDER, AND KELLOGG, '94, - - - - - - - - 194

SUGAR:
Design of Machinery for a Sugar Refinery. KOEZLY, '75, - - 8
Manufacture of Cane Sugar (Experimental Determination of Power). RAE AND MORRIS, '84, - - - - - 120
Manufacture of Sugar. AGUILERA AND COTIART, '86, - - 163

SULPHUR:
Properties of Sulphur Dioxide. ATRISTAIN, HALL, AND LAWRENCE, '90, - - - - - - - - - - 178

TAN:
An Experimental Determination of the Efficiency of Tan for Fuel, at Procter's Tannery, Jameson City, Pa. MURRAY, '92, - 185

TIN:
On the Properties of Triple Alloys of Copper, Tin, and Zinc.‡ COSTER, '77, - - - - - - - - - 30
Researches on the Triple Alloys: Copper, Zinc, and Tin § JOBBINS, '82, - - - - - - - - - - 82

TOOLS:
The Best Cutting Speeds of Tools Obtained by Experiment. TAYLOR, '83, - - - - - - - - - 101
The Construction of Machine Shop Tools. GSANTNER, '78, - 41

TRAINS:
Resistance of Railway Trains. RANDOLPH, '83, - - - 99
The Construction and Management of Roll Trains. HEWITT, '74, 3

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VOL.

TRANSMISSION:
Transmission of Heat from Steam to Water through Coils of Iron Pipe. KOPP AND MEYSTRE, '93, - - - - - 190
Transmission of Power by Compressed Air.* ZAHNER, '78, - 39
Transmission of Power by Means of Wire Ropes.† STAHL, '76, - 22

TRUSS:
Design for a Roof Truss. SCHOENBORN, '87, - - - 168
Review of a Truss Roof over Skating Rink, and a Design of a New Truss to Replace the Former. POST, '86, - - - 161
Review of the Roof Truss of Jersey City Passenger Depot of the C. R. R. of N. J. WHITLOCK, '90, - - - - 178

TUGBOAT:
Review of Engines of P. R. R. Tugboat "Blue Bonnet." MCELROY AND PARSONS, '87, - - - - - - - 164
Review of Engines of P. R. R. Tugboat "Delaware." DILWORTH AND MACHOLD, '85, - - - - - - - 139
Review of Engines of Steam Tugboat "W. E. Cheney." AIKIN, '79, 56
Review of the Machinery of the Tugboat "Coal City." DRUMMOND AND SMITH, '88, - - - - - - - 172
Test of a Compound Marine Engine with Caufield Piston Valve on Tugboat "America." DIXON AND WOLCOTT, 91, - - 182
Test of Triple-Expansion Engines and Boilers of Ocean Tug "Plymouth." ANGELL AND JONES, '94, - - - -

TURBINE:
Design for a Jonval Turbine. BRÜCK, '78, - - - - 46
Design of a Turbine Water Wheel. YAMADA, '75, - - - 9
Test of a Dow Steam Turbine. HAMILTON AND KOLLSTEDE, '94, 195
Turbines. WOODBRIDGE, '86, - - - - - - 157
Turbine Water Wheel. MAGRUDER, '81, - - - - 67

TYPE:
Typewriters. FECHHEIMER, '90, - - . - - 177

VALVE:
Discussion of Cut-off Valve Gears for the Corliss Engines. SLACK, '86, - - - - - - - - 162
Eccentric and Valve of Steam Engine (Comparison of Existing Types). THOMAS, '84, - - - - - - 123
Safety Valves. MILLER, '84, - - - - - - 110
Test of a Compound Marine Engine with Caufield Piston Valve on Tugboat "America." DIXON AND WOLCOTT, '91, - - 182
The Joy Valve Gear. ROBERTS, '84, - - - - - 115
The Joy Valve Gear *versus* the Stephenson Link Motion. HENDERSON, '83, - - - - - - - 106
A New Locomotive Valve Gear and System of Compounding. CONNET, '89, - - - - - - - - 197

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VOL.

VAPOR:
Some Mechanical Properties of Vapors, Especially Steam. ERDMAN AND WALKER, '91, - - - - - - 180
Steam, Ether, and Other Vapors as Working Substances in Heat Engines (Original Calculation of Efficiency). GANTT AND MAURY, '84, - - - - - - - - 118

WATER:
Compound Engine and Water Wheel Tests (Determination of Power Required for Running Saw Mills). MARTINEZ, '85, - 141
Design for an Iron Water Wheel. LEAVITT, '75, - - - 4
Design for a Turbine Water Wheel. YAMADA, '75, - - - 9
Determination of Water Consumption of a Ball & Wood Engine Under Light Loads. COOK AND LORD, '93, - - - 188
On the Design and Efficiency of a Vertical Water Wheel. ARROYO, '81, - - - - - - - - 80
Experimental Determination of Efficiency of a Pelton Water Wheel. MCCOLLOUGH AND WUICHET, '91, - - - 183
Test of Water Consumption of Rollins Engine Under Light Loads. GILMORE AND MACCORD, '94, - - - - - 196
Turbine Water Wheel. MAGRUDER, '81, - - - - 67
Water and Steam as Motive Powers. WETZLER, '82, - - 90
Water Consumption of a 50 Horse-Power Ball & Wood Engine. CORBIN, '94, - - - - - - - -
Water Filtration. EMMET AND PEARCE, '91, - - - - 182
Water Supply of Cities. BIRCHARD, '78, - - - - 44

WAVE:
Wave Line Theory. MAGOVERN, '81, - - - - - 73

WELDING:
Electrical Welding. REID AND UHLENHAUT, '88, - - - 169

WIND:
A Dissertation on the Theory and Practice of Windmills.* WOLFF, '76, - - - - - - - - 24
Wind Motors. FRAENTZEL, '83, - - - - - 103

WIRE:
Effect of Moisture on the Insulation of Wires. DE LA ROSA, '91, 179
Temperatures of Wires Carrying Electric Currents. GRISWOLD, '88, - - - - - - - - - 170
Transmission of Power by Means of Wire Ropes.† STAHL, '76, - 22
Wire Rod Rolling and Wire Drawing. WALL, '75, - - - 10

WOOD:
Investigation into the Strength and Other Properties of Certain Woods Used in Engineering.‡ JONES, '78, - - - 37

---

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VOL.

Review of a Plant for the Manufacture of Wood Spirit and Acetate of Lime, at Galeton, Pa. CORBETT AND WELLS, '92. - - 185

The Cuban Woods Useful in Engineering (an Experimental Investigation).* ESTRADA, '83. - - - - - 98

WORKSHOP:

Design for a Workshop. RENDON AND SILBER, '85. - - - 151

ZINC:

On the Properties of Triple Alloys of Copper, Tiu, and Zinc † COSTER, '77. - - - - - - - - 30

Research on the Triple Alloys: Copper, Zinc, and Tin.‡ JOBBINS, '82. - - - - - - - - - 82

BOOK NOTICES.

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ENGINEERING FALLACIES.

AN ADDRESS TO THE GRADUATING CLASS OF THE STEVENS INSTITUTE OF TECHNOLOGY. DELIVERED BY PRESIDENT HENRY MORTON.

Gentlemen of the Graduating Class: There are a number of popular fallacies which, as mechanical engineers, you are likely to encounter in the course of your professional work, and which, as experience has shown, may sometimes lead even able men astray when met with in a new guise, and which are also occasionally not easy to expose or explain to the ordinary observer. As my own experience during the last 30 years has brought me in contact with quite a number of these, I believe that I may do you a service by reviewing some of my experiences, and by calling your attention to some general principles or rules for dealing with such subjects which I have found eminently useful.

In the first place, though it may seem almost superfluous to mention such a thing, every engineer or investigator who undertakes the examination of any new project involving an assumed discovery of new laws or modes of action among the forces of nature, must hold with absolute confidence the great doctrine of the *conservation of energy*, with its direct corollary relating to what is technically called perpetual motion.

This doctrine may be briefly stated as follows:

No item of energy in the universe ever perishes, nor is any item of energy ever added to the existing supply; the only changes

possible are the transformations of energy from one form into another. Thus heat energy may be *developed from* electrical energy, or from chemical energy, or from mechanical energy, but for every unit of heat energy developed, an exact equivalent of the other form of energy must disappear.

Proteus-like, energy can take all shapes, but must leave one to assume another.

It can only *transform*, and can in no wise *multiply* itself.

It is just as impossible to create energy as to create matter, and if any process is presented which claims to get out of a pound of coal more energy than it is known to possess, or out of the work of a horse more than its known amount, it should be regarded as precisely equivalent to the claim that 10 chairs could be made into 11 or 12 by some special grouping or arrangement of them.

In other words, we should regard it as either a piece of legerdemain or of oversight and error of observation.

In one of its simplest forms of application this principle amounts to the familiar statement of the impossibility of "perpetual motion."

It may be well to remark here that this term, as used in this connection, does not mean indefinitely continued motion; for this, where no resistance is encountered, might manifestly exist, and may be said to be illustrated by the heavenly bodies.

Perpetual motion means the doing of work without expenditure of energy, as would be illustrated by a machine which once started would continue to saw wood or even overcome the friction of its own journals without further supply of energy.

Strange as it may seem, even in this crude form this fallacy still crops out, and I have within a year encountered it among intelligent and, in a general sense, well-educated people, and I will therefore venture on a word of suggestion as to the best means of treating such cases.

In the first place, as a rule at the present time, even those who suppose they have discovered a means of creating energy, by the

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* To be inserted opposite page 247 in the July *Indicator*.

† *Journal* of Franklin Institute, March, 1887.

use of mechanism, do not go so far as to suppose that a machine can move itself, but only believe that by certain combinations a given amount of energy or work may be developed or increased into a larger amount, and in such cases the best argument to open their eyes to the fallacy of their plan is the *reductio ad absurdum* which will be reached by suggesting the connection of the end of their mechanism where the increased "power" is supposed to be available with the starting point where the small driving force is to be applied.

Thus, suppose an inventor of this sort comes to you with a train of wheelwork, levers, etc., by which one man is to propel a train of cars or the like.

It is generally useless to follow out the steps of the mechanism and to point out exactly where a false assumption has been made. If he can appreciate the point at all, he will consider it simply as a matter of detail which he will be able to improve on further study; but if you pick out the final wheel which is to give motion to the whole train of cars he will, of course, admit that it will turn around with many times more power than a man could exert.

You will then propose that this should be connected directly with the crank or lever at which the man was to work, when it would manifestly do the man's work and have a large amount of power left over to run the train, thus dispensing with the man's services as soon as he had started the apparatus, and making the machine self-driving.

In curable cases, where no fraud is involved, this will be sufficient; but, too often, the inventor of a perpetual motion machine is beyond the reach of reason, as was the case with the one who came to Arago for an explanation of the fact that his perpetual motion machine would stop.

Not infrequently such plans involve a mechanical fraud by which the driving force is conveyed to the visible mechanism from a concealed source of power.

In such cases there is an opportunity of applying close and inclusive observation and some ingenuity in order to detect the fraud.

An admirable instance of this is furnished by the history of a small model in the collection of the Franklin Institute at Philadelphia, which was made about 80 years ago by Isaiah Lukens, at the suggestion of Mr. Nathan Sellers, for the purpose of exposing the fraud involved in the then famous Readhefer perpetual motion machine, in which large sums of money were sunk, as they have been in the "Keely motor" and like schemes more recently.

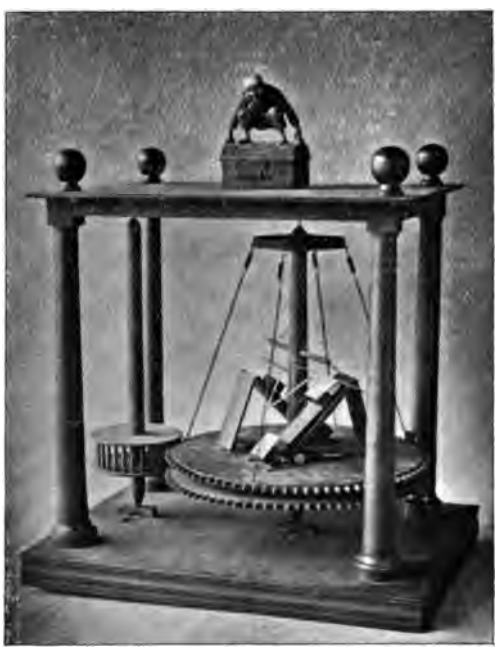

FIG. 1.

This model, represented in the accompanying engraving, Fig. 1 consists of a horizontal circular table, attached to and supported by central vertical shaft, resting on a pivot below and steadied by a urnal held in a framework above. Two inclined planes mounted

on wheels, rest on this circular table, and each inclined plane has on it a car containing two removable weights.

The inclined planes, and also the cars, are attached to levers which are supposed to transmit to the central shaft the tendencies of the inclined planes to run from under the cars and of the cars to run down the inclined planes, and these tendencies are supposed to cause rotation of the central shaft, carrying with it the table and all the parts on it.

This arrangement is admirably *simple* in more senses than one, but, wonderful to relate, it *seems to work.*

If the weights are taken out of the cars the machine comes to rest, but starts up again as soon as they are replaced, and, *under favorable conditions*, will continue to run indefinitely.

Here is a phenomenon which might well startle a novice, but he would do well to hold fast to his faith in the conservation of energy and insist on a further investigation into the interior of the apparatus, for this is what such an investigation would reveal:

A train of clockwork driven by a spring is concealed in the base of the machine, and can be wound up by a slight motion of one of the ornamental knobs on the frame of a glass case which covers and locks up the model beyond seeming possibility of tampering.

This clockwork drives a small plate on which rests the pivot of the central vertical shaft, and the various frictions are so adjusted that when the cars are loaded the weight so given will make the friction of the little plate sufficient to drive the shaft, but when the weights are removed this friction is too slight. An attendant once a day touching the outside case for a moment, under pretense of dusting or the like, can keep it wound up perpetually.

Such, then, is the structure and such the mode of operation of this very ingenious model, whose history, which is also extremely interesting, I will now give.

In the year 1812 Mr. Readhefer applied to the Legislature of Pennsylvania for a grant of funds to carry out his great invention

of perpetual motion, and a committee of experts, consisting of Messrs. Henry Voight, Robert Patterson, Nathan Sellers, Oliver Evans, Archibald Binney, Lewis Wermerag, Josiah White, and Samuel D. Ingham, was appointed to examine the matter.

The machine to be examined was set up in a building near the banks of the Schuylkill River in Philadelphia; and, on a day appointed, the above-named Commissioners went out to inspect the apparatus, Mr. Nathan Sellers taking with him his son, then a lad, but afterward the father of Prof. Coleman Sellers, E. D.

When the Commissioners arrived at the location, they found that the door of the room containing the machine was locked, and the key missing, so that their study was confined to an inspection of the apparatus through a barred window.

Even this limited view, however, was enough for the sharp eyes of young Coleman Sellers. The machine had a set of teeth on the periphery of the rotating table which geared into another wheel whose axle was supposed to transmit the power to some other point where work was to be done.

Young Sellers, looking through the window, noticed that the faces of the teeth in the two wheels were polished by wear *on the wrong sides.*

This will be clear from a glance at the accompanying diagram, Fig. 2.

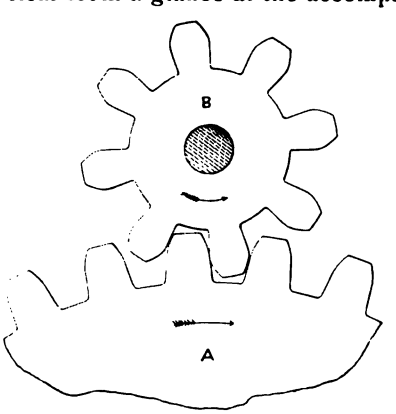

FIG. 2.

Let A be the rotating table driving the gear wheel B in the direction of the arrows; then, clearly, the front faces of the teeth of A will press against the rear faces of the teeth of B, and these faces will be polished by friction.

If, however, it is the front faces of the teeth of A and the rear faces of those of B that are polished, it is manifest that B must be driving A. This is what young Sellers noticed and pointed out to his father as proving that the perpetual motion machine in place of driving the gear wheel, was being driven by it from some concealed source of power.

Satisfied as to the fraudulent character of the Readhefer machine by this observation, Mr. Nathan Sellers concluded that others might be best satisfied by a sort of homeopathic object lesson.

He therefore went to Mr. Isaiah Lukens, a very skillful mechanician of that date, and had him construct the model above described. This he at first exhibited to a number of persons, including Mr. Readhefer himself, without explaining its true "inwardness."

Mr. Readhefer was so impressed that he privately offered Mr. Sellers a large share of his inventions if he would tell him "how it was done."

It is hardly necessary to say that this offer was declined, and the true *modus operandi* in due time made public.

This matter is so curious in many respects that I will here read a copy of the resolution under which this commission acted.

Whereas, The interference of the Legislature of Pennsylvania in causing an inquiry to be made relative to the perfection or imperfection of newly invented machinery is not without precedent; and

Whereas, It has been represented that Charles Readhefer, of the County of Philadelphia, has invented a machine declared not only by the inventor, but by many intelligent persons, to possess the power of self-motion; and

Whereas, Should it be ascertained that these opinions are correctly founded, not only great honor would be conferred upon the

Commonwealth, but incalculable advantages would be derived from the invention by the people of the United States especially, and by mankind in general; and

Whereas, On the other hand, should the machine be found to be imperfect, the public interest would be promoted by exposing its fallacy; and

Whereas, The Legislature of this Commonwealth reposes confidence in the integrity and qualifications of Henry Voight, Robert Patterson, Nathan Sellers, and Oliver Evans, of the City of Philadelphia; Archibald Binney, Lewis Wermerag, and Josiah White, of the County of Philadelphia; and Samuel D. Ingham, of the County of Bucks; therefore

Resolved, By the Senate and House of Representatives of the Commonwealth of Pennsylvania, in General Assembly met, that Henry Voight, Robert Patterson, Nathan Sellers, Oliver Evans, Archibald Binney, Lewis Wermerag, Josiah White, and Samuel D. Ingham be, and they are hereby, requested to make a strict examination of the machine invented by Charles Readhefer, and to make specific representation respecting it as its alleged importance and the public expectation require.

Resolved, That the Secretary of the Commonwealth be, and is hereby, requested to transmit a copy of the foregoing preamble and resolution to each of the persons named therein, and also to Charles Readhefer.

(Sig.) JOHN TOD,
Speaker of the House of Representatives.
P. C. LANE,
Speaker of the Senate.

In the House of Representatives,
December 14, 1812.
Read and adopted.
GEORGE HECKERT,
Clerk of the House of Representatives.

In Senate, December 17, 1812.
Read and adopted.
JOSIAH A. MCJIMSEY,
Clerk of the Senate.

Then follows the certificate of the Deputy Secretary, and his tter to Nathan Sellers.

The driving of a supposed motor through machinery which is supposed to be driven by it is a very general method of deception.

Thus I have seen one of these supposed "motors" set up in a shop and connected by belting and shafting with a number of lathes and other machine tools. When everything was running it was impossible by mere inspection to say which may have been the real "driver," since the power might have been transmitted through a hollow journal to any one of a number of points in the system; but, you may be quite certain, in such cases, that it is *not* the supposed "motor" if the conditions of its operation are inconsistent with the doctrine of "conservation of energy."

In the case of these fraudulent structures a fortunate accident may aid detection.

About 20 years ago, a Mr. Paine had an electro-magnetic engine in Newark, in which many persons whose names are not unknown to fame, and who certainly ought to have known better, "took much stock," in the literal as well as figurative sense.

Being in Newark on some other business, I was waited upon by Mr. Paine and invited to see the machine. I accepted the risk (which I will presently explain) attending such a visit, and went with him.

The apparatus was shown off with great success, starting with full velocity the moment a connection was made with a little battery of four cells, driving lathes, sawing wood, etc., in a way that demonstrated several horse-power at least. I need hardly say that I was not convinced that perpetual motion had been discovered, but only looked out for the trick.

Nothing, however, could be demonstrated, without taking the ponderous machinery to pieces. Near the end of my visit, however, in connection with a pseudo-explanation of some point, Mr. Paine once more connected the battery; whereupon the machine, in place of starting promptly as before, made a few turns and stopped.

This was, of course, accounted for by the inventor as caused by some derangement of parts; but, as, a few minutes later, I went

downstairs, I looked at my watch, and found that it was five minutes after 6 o'clock. The building, at large, contained a steam engine; and power was confessedly used in all other parts except those occupied by Mr. Paine. This remarkable failure to start just about 6 o'clock, therefore, revealed the actual source of energy. The little battery, without doubt, either operated a belt shifter in a room below, or signaled a confederate similarly located for a like purpose.

Not long after, Mr. Paine and his electric engine were unsuccessfully sought for by some of his stockholders, and all that was found was a portion of the iron frame of the machine showing an interior passage for a belt to act on its axle from the room below.

The connection between the arrival of 6 o'clock and the stoppage of the motor which I had noticed in my visit, and had of course referred to its true cause, was thus fully demonstrated.

The risk to which I alluded in connection with such a visit is one of reputation. An ordinary sense of politeness hardly allows one, when visiting a man's workshop on his own invitation, to treat him as if he were a cheat and his statements as falsehoods, even if we so believe them to be; and thus one, from mere politeness, is almost sure to say something which may be quoted by interested parties as an indorsement; and such statements are very difficult to correct and explain, when they have once been put in circulation.

It is therefore a very good plan, when one is requested to look into such a matter, to decline unless an agreement is made that every interior detail of the machine shall be exposed to your inspection. In nine cases out of ten this will relieve you of any further solicitation.

On the other hand, to make any agreement not to reveal what you see, as was asked in some cases, as I know, in connection with the Keely motor, is of course what no sensible man would do, as it would make it possible to use his name in support of what he might have detected to be a fraud.

It may seem almost needless to say so much on the subject of these gross and conspicuous fallacies; but, while the stock of the Keely Motor Company, in the face of repeated exposures and years of unfulfilled promises, has to-day a value in the market; and when not only such daily papers as are notorious for their lack of truth, honor, or decency, but even respectable journals, will publish articles seriously advocating such plans, it is evident that even such fallacies need to be met and exposed by the intelligent engineer.

Besides these fallacies, which involve more or less intentional deception, we encounter others which are the result of perfectly honest, but none the less fatal, mistakes in observation or experiment.

A striking instance of this is furnished by one form of what is known as the aero-steam engine. This was a plan for admitting air into the cylinder of a steam engine at a certain point of the stroke, with a supposed gain in efficiency. A number of experiments were made within my own knowledge with a small engine, or, in fact, model, which seemed to demonstrate conclusively the advantage of this modification.

When the air was admitted, everything else remaining the same, the engine made 20 per cent. more revolutions in a minute against the same resistance.

This was, in fact, thought to be conclusive as to the advantage of the plan. On further investigation, however, it was found that the boiler supplying the steam engine was so inadequate that it could not fill the cylinder for a rapid stroke, and that thus an "exhaust" or back pressure occurred at each stroke when the engine was running fast. The admission of air at a certain point relieved this back pressure and actually increased the duty, but even when so increased it was inferior to what it should have been with a well-proportioned boiler.

This is, in fact, a type of a large class of fallacies, one or another of which we encounter almost daily.

An inefficient or defective machine or process is taken as a standard, and some attachment or modification is made which

greatly improves the result, and it is thence assumed that this attachment or modification would be of equal efficiency with machines or processes in a normal condition.

Thus, for example, a plan for blowing steam into the ashpit of a boiler furnace was, many years ago, extensively advertised, and very remarkable testimonials were shown as to its actual efficiency.

On investigation, it however turned out that these cases of success occurred where there was a great want of draft in the furnaces, and *any* means of increasing it would therefore have proved beneficial.

The steam blast was, however, a much less efficient way of increasing the draft than any of the well-known methods. Such an example teaches the importance of positive measurements in all cases, and the comparison of results with well-known and established standards.

Another example of a practical result apparently proving an efficiency which did not exist, was brought to my attention, some time since, in connection with a pump which developed a pressure much beyond that which would be estimated by calculation of the force applied on the known area of its piston.

It turned out, however, that the piston was so loose that the water passed freely from one side to the other, and thus the pump acted only on the inward stroke, when the piston-rod played the part of a plunger whose reduced section, as compared with the piston, accounted for the increased pressure obtained.

This condition of affairs was, of course, betrayed by the small amount of water delivered, as soon as that was observed.

The conditions in this case will be fully illustrated by the accompanying diagram, Fig. 3, in which A B indicates a pump cylinder with a piston C and piston-rod D. Also inlet and outlet valves and passages as shown.

If, now, the piston fitted tightly and was moving towards the left it would force water before it through the upper or outlet valve and draw it in behind through the inlet valve below.

If, however, the piston was so loose that the water could pass freely around it, then, clearly, no water would be drawn in and both inlet valves would close; but the piston-rod, as it was thrust in, would displace its own volume of water and force that amount through the outlet. On the reverse stroke no water would be forced out; both outlet valves would be closed, but enough water would enter to fill the space vacated by the withdrawal of the piston-rod.

While the volume of water delivered would be thus immensely reduced, its pressure would be proportionally increased, for the force applied to the piston-rod, in place of being diffused over the entire face of the piston, would be concentrated on the cross-section of the rod.

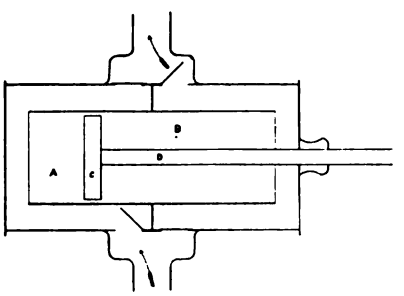

FIG. 3.

The lesson this teaches is, when a result is obtained at variance with established principles, don't look for a new law or a new force, but suspect an error of experiment or derangement of the machine.

Such examples as I have just cited teach us also another lesson, which may be embodied in a very brief maxim, which is this, "Never make two experiments at once."

That is, when you are investigating a subject and estimating the effect of this or that modification or improvement, never make two changes at once, for then you may easily assign the new result to the wrong one of the two possible causes.

Some remarkable examples of this error were furnished some 25 or 30 years ago in connection with what then excited no small interest among steam users—namely, the "anti-incrustator." This

consisted of a group of small magnets sustained by an insulating support in the steam space of a boiler and connected by a copper wire with the shell of the boiler at the other end. This was supposed to prevent the formation of scale in the boiler.

If unexceptionable certificates and the testimony of the most reliable witnesses as to practical results could have proved anything, this was thoroughly demonstrated to be an efficient apparatus. For several years it had a most successful career.

The stock of the company went up like that of some other more recent companies, and, what is more, *stayed up*, and the anti-incrustators were put into boilers by the thousand. In a few years, however, with wonderful suddenness, the anti-incrustator went out of favor, and became a matter of history only.

To explain each instance of its success in operation would be, of course, impossible, but one prominent one will suffice as an example of a large class.

This was brought to my attention at the time by Prof. Coleman Sellers, E. D., of Philadelphia, who was one of the few who at that time declined to accept the evidence presented as sufficient to establish a claim itself intrinsically unscientific and improbable.

A friend of Mr. Sellers had tried some of these incrustators on boilers of his own, and, finding that they ceased to form scale, was convinced, and took a large interest in the company.

In conversation with Mr. Sellers he stated this circumstance, whereupon he was asked: "Did you not make some other change at the same time?" "None of any account," he replied. "To be sure, while the boiler was opened to put in the anti-incrustator, we took advantage of the opportunity to disconnect the mud drum, and in place of it connect the feed with a disused boiler alongside, which we employed as a feed-water heater."

Now let me point out that one of the chief scale-producing elements in the Philadelphia water is sulphate of lime, which is less soluble in hot than in cold water. With this fact before you, you will at once see that this gentleman had provided a most admirable

"anti-incrustator" in his feed-water heater. Here was a large mass of water so heated as to establish only gentle currents, and with a slow circulation, by reason of which the water remained in it a considerable time, and could thus deposit the sulphate of lime, as that became insoluble through the rising temperature. The sulphate of lime also, of course, carried down with it other suspended matters, as we all know it will under such conditions.

Here was a clear case of trying two experiments at once, and of assigning the result to the wrong cause.

Next to these, which may be called mechanical fallacies, we come to a more refined and abstruse class, which may be described as chemical fallacies.

Very many who may be quite able to see that no combination of levers, pulleys, wheels, etc., can make a machine operate itself without external supply of energy, or can convert one horse-power into two, are not able so readily to see why a pound of coal may not be able to produce more than its regular equivalent of heat.

One of the forms of this fallacy which is most active at the present day is expressed with charming *naiveté* in an article appearing March, 1880, in the *Popular Science Monthly*, with the title, "Water as Fuel," also in a paper read before the Engineers' Club in Philadelphia, and published in the *American Gas Light Journal* of February 16, 1880.

The leading fallacy developed in these articles is that involved in the title first quoted, "Water as Fuel."

To anyone understanding the actual conditions this title would be even more absurd than such a one as "Ashes as Fuel," "Rest as a Source of Motion," or the like.

Water is simply the ashes of a perfect combustion, and is no more capable of becoming fuel than the most perfectly burned ashes from a wood or coal fire.

Fully to realize the true relation of this and other like matters, we must take a rather wide view of our chemical surroundings here, as we live on the earth's surface.

We are surrounded by a practically unlimited supply of diluted oxygen in the form of the atmosphere, and all practical combustion must consist in a union of one or another fuel with this oxygen in the air.

While there are hundreds of other chemical combinations capable of producing heat, and which might with great propriety be called combustions, none but those involving the union of some fuel with atmospheric oxygen are practically available; and while, from a purely philosophical standpoint, it is just as proper to call oxygen the fuel and coal the supporter of combustion, yet, in their existing practical relations, it is far more convenient and appropriate, and fully as accurate, to look upon atmospheric oxygen as the universal and freely supplied supporter of combustion, and coal, wood, and other materials capable of energetic union with it, as combustibles or fuels.

It is these for which we pay, and whose economical consumption is of importance, and the atmospheric oxygen may be safely taken for granted, with only such limitations as to secondary effects of its wasteful use as will, of course, be familiar to all engineers.

Realizing this, it will be evident that the value of any fuel depends primarily upon its capacity of uniting with the oxygen in the air, and that the addition to it of anything which does not possess such a capacity can in no way add to its heat-producing capacity, though, of course, it may render it more convenient of application in certain cases. To illustrate this:

The heat energy in ordinary illuminating gas is by no means greater than that present in the coal from which it was made, but, on the contrary, is vastly less, yet, nevertheless, its convenience of application renders it actually more economical to apply it to a vast number of uses, notwithstanding an immense loss of total heating capacity.

What, then, is the true office of water in its relation to fuel, properly so called? Simply, that of a vehicle which, at a certain sacrifice of total efficiency, nevertheless, facilitates the application

of the heat energy (derived exclusively from the fuel) under certain circumstances.

In numerous cases solid fuel cannot be brought conveniently in contact with the material to be heated, and then it may be desirable, even at a certain loss of total effect, to turn the solid fuel into a gas for the sake of this increased convenience of application and consequent special efficiency.

In such cases, water may become a useful agency, but you cannot too firmly fix in your minds the fact that its beneficial effects depend solely on this facility of application, and not by any possibility of any contribution by it to the total energy developed in the combustion of the fuel. The oxygen and hydrogen of the water have already developed in their mutual union all the potential energy they possessed in this relation, and, before they can again exhibit any such force, it must be supplied to them from some other source, such, for example, as the combustion of actual fuel, and then what they give out again will be exactly what was thus supplied to them, and no more.

When, therefore, we encounter such statements as that by the use of water with coal the thermal equivalent of the carbon can be practically raised from a theoretical maximum of 14.300 heat units to a practical efficiency of 18.000 heat units, or that six pounds of carbon whose theoretical maximum is 85.800 heat units, can, by the aid of nine pounds of water, develop 124.000 heat units, let us not mistrust our previous impressions and fall into doubt as to the truth of the great theory of conservation of energy, but look out sharply for a fallacy in the reasoning which has led to such a conclusion.

We should remember, in fact, that while very few things are so improbable that they might not be established by sufficient evidence, yet that the amount of evidence must be vastly increased when a seeming result is at variance with established laws, and that we will be well repaid for the closest scrutiny and the utmost deliberation by the avoidance of disastrous errors.

Another common source of error and consequent loss is the neglect in the consideration of a subject of what may sometimes seem trifling practical details, but which often control the question of success or failure.

Thus, for example, it was seen at quite an early date that a hot-air engine was theoretically a more economical motor (if questions of practical detail were neglected) than a steam engine. Immense sums of money and a vast amount of the highest inventive genius have been expended on the development of such engines for general use.

The small practical details of excessive bulk in the machinery, consequent friction, the use of very high temperatures, and the like, have, however, limited the application of the air engine to a very narrow field.

In like manner, theoretically considered, the magneto-electric machine, deriving its exciting field-of-force from permanent magnets, is manifestly more economical than a dynamo-electric machine whose exciting field-of-force is maintained only by a constant expenditure of active energy. Yet, as a matter of fact, this theoretical economy is more than balanced by the practical impossibility of securing great intensity of magnetic field with permanent magnets, so that the losses caused by the greater friction and electric resistance present in the larger and more complex magneto-machines are greater than those involved in the constant generation of a magnetic field by the use of an electric current in the dynamo machines.

Some curious fallacies have been presented to the public within the last few years resulting from a failure to recognize that a horse-power did not express an amount of work, but only the *rate of doing work*. Thus in order that a horse should develop one horse-power he must raise 33,000 pounds 1 foot high *in each minute* of the time he is working, and thus if he works for 10 minutes he will do the amount of work represented by 330,000

foot-pounds, or if he works for 10 hours his work will be 60 times as much as that, or 19,800,000 foot-pounds.

About a year ago a machine was exhibited which may be briefly described as a steam engine employing liquefied ammonia in place of steam. In exhibiting it, its promoters caused it to raise 33,000 pounds 1 foot high in 10 minutes, and, reckoning this as a horse-power, the machine showed a remarkable economy as compared with an ordinary one horse-power steam engine. None of the promoters or unprofessional spectators seemed to notice the fallacy or to realize that if this engine and an ordinary one-horse steam engine had been working side by side, sawing wood, for example, the steam engine would have done as much work or sawed as much wood in each minute as the ammonia engine did in 10 minutes, and that thus, at the end of the day, the work or wood pile of the steam engine would be 10 times larger than that of the ammonia engine.

In fact, the ammonia engine was not a one horse-power machine, but a one-tenth horse-power machine.

This incident brings to mind another error which sometimes causes curious mistakes in connection with this same measure of the rate of doing work—i. e., the horse-power.

The standard horse-power, 33,000 foot-pounds per minute, does not mean all that a horse can do, but what he can keep up steadily for eight hours a day.

In starting a heavy load, or in jumping or running, a horse can develop work for a few minutes at a rate many times as great as this. The same is true of a man. Doing steady work hour after hour a man can develop about one-tenth to one-fifth of a horse-power, according to circumstances, but under the most favorable conditions an ordinarily strong man can develop work for 15 seconds to a minute at the rate of a horse-power. This is on record in "A Treatise on the Construction of Cranes," by J. Glynn, Crosby Lockwood & Co., London, 1880, but is not, I think, generally known.

My attention was first called to it in the following way: I was asked to test a dynamo machine for which the claim was made that it was many times as efficient as the best Brush or Weston dynamos.

I suggested that this was not possible, because the above-named machines had efficiencies of between 80 per cent. and 90 per cent. of a theoretical maximum.

The reply to this led to the following questions and answers:

Q. How much power does an ordinary brush arc light require?

A. About one horse-power.

Q. How does a man-power compare with a horse-power?

A. As about one-fifth to one-tenth to one.

Q. If then one man with the dynamo under discussion can run one Brush arc light, will not that prove the machine to be from 5 to 10 times as efficient as a Brush dynamo?

To this I replied that I would like to see it done.

In due time there came to hand a large flywheel mounted on a frame, with a pulley for belting to the dynamo, and a winch to turn it by.

All being arranged it was found that a strong man could in fact keep up an arc light with this apparatus *for about* 50 *seconds.*

As soon as this was demonstrated, a dynamometer was attached in place of the dynamo, and this showed that, in the same way, the same man could develop about one horse-power for the same time.

It was curious also to observe how completely a man of ordinary strength was exhausted in this or a shorter time when expending energy at this high rate. Experiments narrated in the work above named showed that men practiced in turning a winch could keep up such work for from two to three minutes.

This matter of the true measure of a horse-power frequently comes in as an important practical question.

Thus, in considering motors for street cars, it does not at all follow that a two-horse steam engine or other motor could practically replace a pair of horses. The two-horse engine could exert no

more power in starting the car than at any other time, while the pair of horses could for a few moments work at the rate of 8 or 10 horse-power, and so accomplish all that was needed where the engine would fail.

There are certain erroneous impressions as to the true relations of force, energy, and work, originally derived from our personal sensations, which are constantly encountered. Thus, in connection with the early so-called "demonstrations" of Mr. Keely, there was a constant confusion of "pressure" (which is an example of "force") with "work," or its source, "energy", and the public was constantly told that Mr. Keely had discovered a new and vast power, capable of accomplishing vast results in the way of work, because he showed pressures of thousands of pounds on gauges.

If one holds up a weight in the extended hand he is soon as tired as if he had done a considerable amount of work, and it is therefore natural to feel that the mere exercise of force is equivalent to the doing of work.

Work, however, is a compound entity involving not only the exercise of force but also the accomplishment of motion.

A force of one pound acting by causing motion through 1 foot will do the work of a foot-pound; but a force of a million pounds not moving or causing motion through any distance will do no work.

Work must always be a product of force and distance moved.

A realization of this will save us from the fallacies involved in schemes for the development of "power" from such forces as the expansion of solids or liquids which, though enormous in their intensities, are limited to insignificant distances in their range of motion. The same principle applies as to many proposed forms of magnetic motors, where the intensity of an attractive force is offset by the shortness of its range.

Another instance of an erroneous impression arising in the same way is the very common one that the reaction of an escaping jet upon the vessel from which it flows depends in some way on the

exterior resistance to said jet. If we stood at the stern of a boat, and wished to push the same forward, we could accomplish much more by placing a pole against the shore or some firm obstruction and pushing, than if we had no such resistance to act upon, and, therefore, we feel that if we are trying to propel a boat by driving a jet of water from her stern a better effect will be secured in proportion as the jet strikes against a more and more unyielding resistance.

In fact, however, the energy expended or work done in so propelling a boat depends solely on the energy or work involved in the ejected jet, and is exactly the same whether the jet is thrown above the water level into the air, below the level into the water, or in some other arrangement into a vacuum. A failure to appreciate this well-established fact involved, within a few years, the useless expenditure of a large sum in attempting to drive a boat by water jets expelled at high velocities, under the impression that the greater resistance to the jet after it had left the nozzle, secured by its high velocity, would produce a beneficial effect upon its "reaction" or power to drive the boat.

AN APPARATUS FOR EXPLORING MAGNETIC FIELDS AS TO DIRECTION AND INTENSITY.

BY PROF. W. E. GEYER.

LET a flat coil of wire rotate about a horizontal axis, which lies in the plane of the coil, and passes through its center. Consider the lines of force as also being horizontal and running in a direction at right angles to the axis of rotation. If the ends of the wire are connected to two insulated rings, mounted upon the shaft, a current can be collected by brushes rubbing upon the rings and connected with some external circuit. The current is an alternating one, and, if the speed of rotation is at all rapid, will not deflect a galvanometer needle. The position of the brushes, both with reference to the revolving coil, or to one another, is, of course, altogether without influence on the result.

If the ends of the wire are brought to the well-known split-ring commutator, the current may be more or less commuted. It will become entirely unidirectional, when the brushes rub upon the middle of the half-rings, at the time when the revolving coil is in its most efficient (in this case, horizontal) position. The galvanometer needle, being now urged in but one direction, will be deflected.

Upon the same split-ring commutator place another pair of brushes 90 degrees in advance of the former. A galvanometer connected with these will not be deflected, for the current is now in opposite directions for equal periods.

If both sets of brushes are shifted 45 degrees forward the galvanometers will give equal readings. For, although the currents are interrupted, and to some extent alternating, there is a pre-

ponderance in one direction. Instead of shifting the brushes, we might have caused the lines of force to dip at 45 degrees. The galvanometer readings would again be as above.

We may conceive the field of force as resolved into a horizontal and into a vertical component, and place one set of brushes to draw the maximum current from the horizontal part. The other pair, 90 degrees in advance, will then give the vertical component. By compounding the components we get the resultant as to magnitude and direction.

Let H=value horizontal reading.

Let V=value vertical reading.

Then $\sqrt{H^2 + V^2}$ = the total force.

The direction is an angle whose tangent is $\frac{\text{vertical reading}}{\text{horizontal reading}}$.

As far as I am aware, this method of exploring a magnetic field for direction and intensity by the use of four brushes had not been tried or described, and in 1892 experiments were made, at my suggestion, by Mr. Harold B. Atkins and John T. Schramme, to test its availability for the purpose mentioned. These experiments were resumed in 1894 by Mr. Robert W. Smith and Mr. William D. Pierson, and successfully completed. The following is a condensed description of their apparatus and results:

DESCRIPTION OF APPARATUS.

The exploring coil *a*, Fig. 1, consists of 15 turns of No. 36 copper magnet wire, wound on a brass bobbin *v* three-eighths inch in diameter and one-half inch long. This bobbin has a shank *c* three-sixteenths inch in diameter and 3 inches long, drilled and tapped to screw on a brass shaft 12 inches long, which, for 3 inches on the bobbin end, is three-sixteenths inch in diameter, and for the remainder of its length is one-fourth inch in diameter. This shaft is made in two pieces, it being found impracticable to turn so slender a piece of that length, and the two parts are joined by a nicely fitting brass collar, which also serves to keep the shaft from

sliding in its bearings. The bearings are plain, cylindrical, 6 inches apart; the one at the bobbin end being three-sixteenths inch in diameter, the other one-fourth inch. The enlargement of the shaft, occurring just within the bearing, forms a shoulder, which, like the collar at the other bearing, prevents sliding of the shaft. The bearing at the bobbin end of the shaft carries a bushing one-

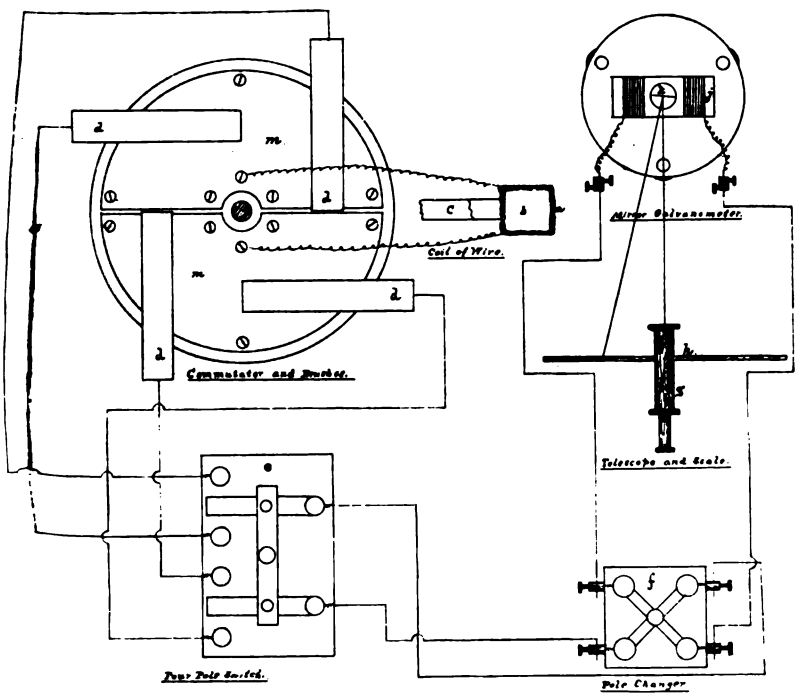

FIG. 1.

half inch in diameter and one-eighth of an inch long, which holds a yoke of hard rubber on which the brush-holder is fixed.

The brush-holder is of hard wood one-eighth thick and 2 inches in diameter and is fastened to the yoke by means of brass screws. It carries on its face four brushes at a quadrant's distance from one another. These brushes consist of eight strips of hard-rolled

copper one-fourth inch wide and 1 inch long, soldered together, and fastened to the brush-holder by means of brass screws. The brushes, together with the brush-holders and yoke, are capable of being rocked on their support, so that the brushes are adjustable to any position.

The commutator on which the brushes rub is constructed as follows:

Upon a boxwood hub, three-fourths inch long and seven-eighths inch in diameter, is fastened a plane disk of hard maple three-eighths inch in thickness and two and one-quarter inches in diameter. This plate is divided into halves by a narrow slot. The brushes rub upon the face of this disk, so that we have what might be called a face-plate commutator. Four set screws in the hub keep the commutator from turning on the shaft, and provide a means of adjusting it, so that it will turn truly.

It may be remarked incidentally that Messrs. Smith and Pierson at first constructed a cylindrical commutator, similar to the one used by Messrs. Atkins and Schramme in preparing their thesis of 1892, with the exception that the material used was copper instead of brass.

After giving it a thorough test, in a course of experiments which consumed two weeks, the commutator was discarded as being unreliable.

The face-plate commutator was found to be a great improvement, giving steady, uniform readings.

The two ends of the winding on the bobbin are brought each to a binding post fastened in the back of the "face-plate," and connected electrically, one to each half of the commutator.

Four wires lead, each from its respective brush, to a double two-point switch, by means of which either set of wires is electrically connected with the galvanometer, a "set" constituting two wires leading from diametrically opposite brushes.

After passing through the switch, the current is led through a reverser, by means of which the galvanometer is deflected first to

one side of the zero point, and then to the other, thus eliminating any error due to a possible change in the position of the scale.

The brushes are so placed that one set takes off the current generated by the horizontal component of the lines of force, while the other set, being placed at right angles to these, takes off the current which measures the vertical component.

The galvanometer used to measure the current generated is the Hartman low-resistance dead beat galvanometer, which consists essentially of a bell-shaped steel magnet suspended so as to swing freely between two coils of magnet wire through which the current to be measured is sent. The galvanometer is very "dead beat," the damping being obtained by means of a heavy cylinder of copper. A small mirror is attached to the steel magnet so as to swing with it, and the deflections are read from a scale through a cross-haired telescope placed at some distance from the mirror, in this case about 14 feet, the scale being reflected into the telescope by means of the mirror.

The coil is rotated by means of a small electromotor, which is run by means of a 10-volt current from the storage battery, the belt being run from a 2½-inch pulley on the motor-shaft to a 1-inch pulley on the shaft carrying the coil.

The speed-regulating device first used was one devised by Mr. Trautvetter, and used by him in his thesis of 1891, and consists of a tuning-fork actuated by an electromagnet through which an intermittent current was sent, the "maker-and-breaker" being on the shaft of the motor.

When the "maker-and-breaker" corresponded in time to the vibration number of the fork, a note was produced which gave the signal for taking the reading. This apparatus, however, was finally discarded, together with all the results based upon its use.

In its stead there was secured from Koenig, of Paris, an electric tuning-fork arranged for stroboscopic vision, which speed-counting device filled with perfect satisfaction the demand made upon it.

It consists, Fig. 2, of a large tuning-fork mounted upon a standard (for the present purpose, horizontally, and vibrating in a vertical plane) and having between its prongs an electromagnet, through which an intermittent current passes, the current being made and broken by means of a tongue attached to one of the prongs and acting in the same manner as the little tongue in an electric bell.

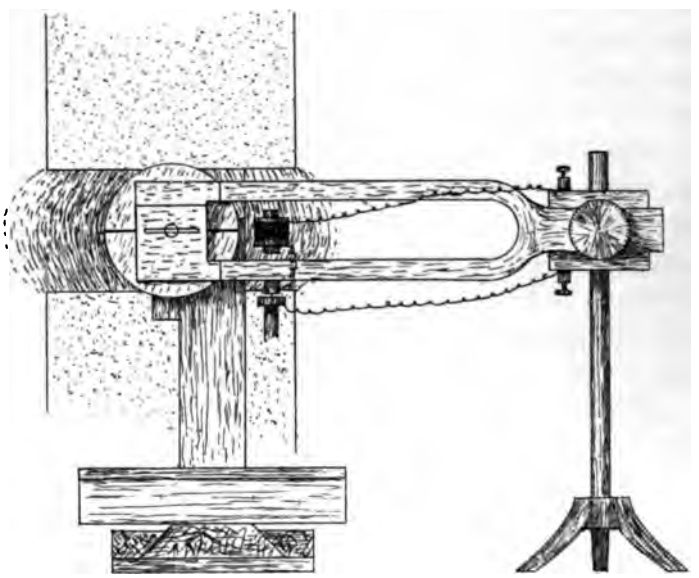

FIG. 2.

The vibration number of the fork is adjustable through quite a range, by means of weights sliding on the prongs; and this range is extended through a series of forks.

On the ends of the prongs are aluminum screens, each with a horizontal slot, and when the fork is not vibrating, the slots are opposite each other, so that one can see through.

Hence, when the fork is in vibration, the slot opens and closes twice for each complete vibration.

The large end of the shaft, Fig. 2, carries a wooden disk with a paper face, upon which is drawn a heavy black diametral line. The operator looks through the slot of the vibrating fork at the revolving disk. If now the disk makes half a turn every time the slot opens, the line on the disk will appear stationary; if the disk revolves too slowly or too fast, the line appears to revolve backward or forward, as the case may be, the speed of this apparent forward or backward motion being greater or less, as the speed of the shaft is more or less perfectly adjusted. The speed is controlled by the pressure of the finger upon the shaft, and can be regulated to a nicety.

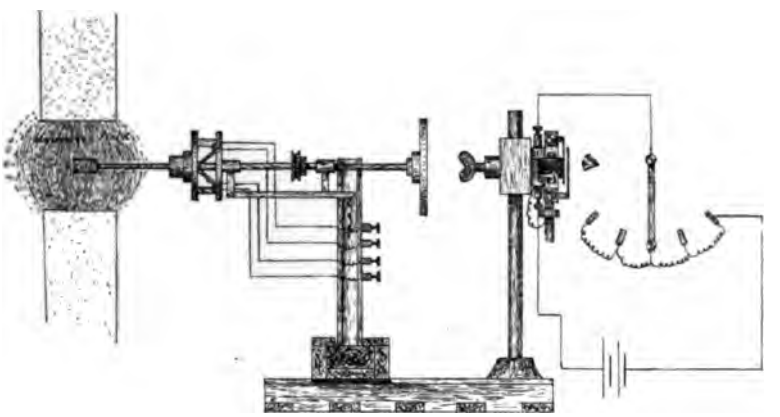

FIG. 3.

The dynamo whose field was explored was a small Westinghouse machine ordinarily used as an exciter for their alternator. It was excited by means of 0.15 ampere from another dynamo.

The two operators were in separate rooms and connected by signals. One operator manipulated the coil and governed its speed, while the other took the readings of the galvanometer. The extreme delicacy of the galvanometer rendered this complete isolation necessary.

The coil, shaft, brushes, etc., were mounted upon a wooden slide rest capable of sliding in any of three rectangular directions.

indicated by X, Y, and Z in the tables; and, by means of scales and indices, the co-ordinates of any position of the coil could be ascertained.

The origin of co-ordinates is taken at the center of the armature, which is also the center of figure of the field magnets. Distances along the axis of the armature are denoted by X. The axis of Y is horizontal, running midway between, and parallel with, the horizontal portion of the field magnets. The axis of Z is vertical. The values of X, Y, and Z are given in inches.

With the idea of testing the accuracy of the apparatus, it was proposed to rotate the dynamo field about the axis of the coil to several different positions, and to take the H and V readings for each new position of the field.

The H and V components would then change for each position of the field, but the resultant should be the same in every case.

Instead of rotating the field magnets, however, the brush-holder was rocked, thus giving components, which, although apparently horizontal and vertical, as a matter of fact, were not, and which changed in value for each new position of the brush-holder.

The resultant of these components, however, should be equal in all cases, so that the operation of rocking the brushes will afford the same means of testing the apparatus that the rotation of the field magnets would give.

The following table gives the results:

TABLE I.

APPARENT HORIZONTAL.			APPARENT VERTICAL			$H^2 + V^2$.	$\sqrt{H^2+V^2}$.
Right.	Left.	H. Average.	Right.	Left.	V. Average		
6	6	6	108	108	108	11,700	108.1
56	60	58	85	85	85	10,589	102.9
94	96	95	36	42	39	10.546	102.7
6	7	6.5	107	108	107.5	11,598	107.7
80	76	78	70	70	70	10,984	104.8

The variation of the value of the resultant is only 2.7 per cent. either side of the mean, showing the theory to be correct and the readings to be reliable.

In Fig. 4 are plotted the results of an experiment when the exploring coil was at first in the position X = 1.5, Y = 3, Z = 0, and moved along by one-half inch at a time to Y = 6. The axis of rotation was parallel with X. The field magnets were excited by

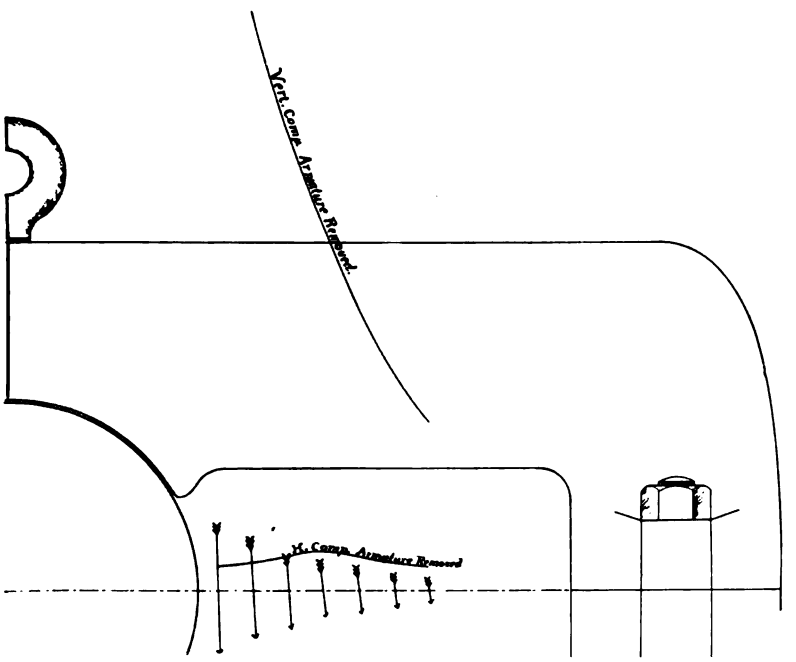

FIG. 4.

0.15 ampere, the armature having been taken out. The arrows of the figure indicate the direction, and, by their length, the relative magnitude, of the component, as calculated from Table II.

On inserting the armature, but leaving it without current, both components, especially the vertical one, were much reduced (see Table III.), since many of the lines of force, which before were stray ones, now passed through the armature core.

Fields.

READINGS.		AM-METER.
Left.	Mean.	Reading.
108	108	.15
86	83	.15
62	60.5	.15
53	52	.15
42	40	.15
32	31	.15
25	24	.15

RTICAL READINGS.			AM-METER.
ht.	Left.	Mean.	Reading.
72	72	72	.15
62	70	66	.15
48	55	51.5	.15
39	44	41.5	.15
30	36	33	.15
24	27	25.5	.15
19	21	20	

V.

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When, however (see Table
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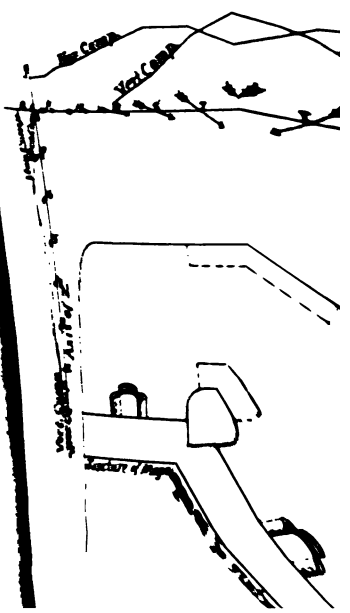

When, however (see Table IV.), the armature was charged with a current of only three amperes, the horizontal components near the armature were very much increased, showing a distortion of the stray field.

In Fig. 5 are plotted the results of experiments on the outside stray field. The sudden change in direction at Y$3\frac{1}{2}$, where the

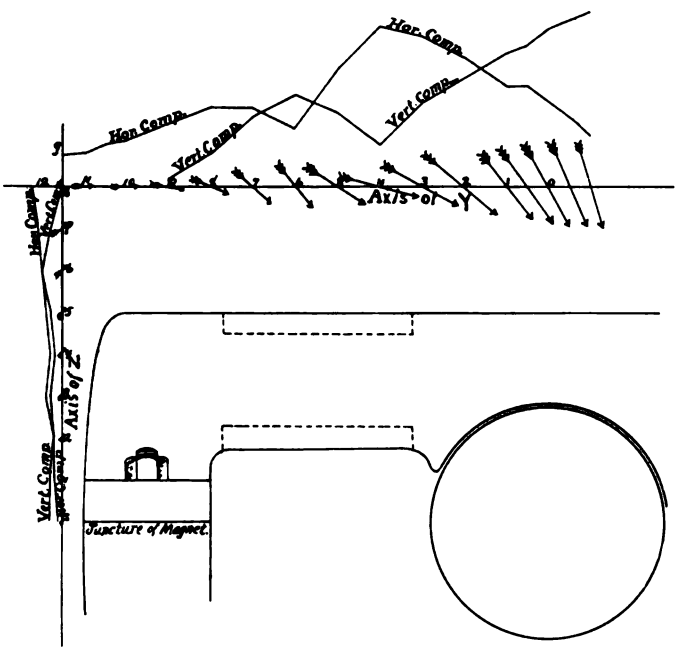

FIG. 5.

cross-section of the iron is reduced to make room for the field magnet wire, is interesting.

By rotating the coil at the standard speed in a field of known intensity, such as that produced by a long helix, the reading could be reduced to some absolute measure.

THE DETERMINATION OF CARBON IN IRON AND STEEL.

BY PROF. THOMAS B. STILLMAN.

THE determination of carbon in iron and steel has probably received more attention in later years from chemists than any other subject in analytical chemistry.

To secure a method at once complete and rapid whereby carbon varying in amounts from 4 per cent. to 0.001 per cent. in different irons and steels could be accurately determined has been a *desideratum*.

Processes that are satisfactory for special grades of irons or steels rarely can be relied upon in general practice.

So important has this subject become to the metallurgical world that committees acting in union from Sweden, England, and America* have been appointed to determine not only the best methods of iron and steel analysis, but also to analyze standard samples of iron and steel, compare the results and select methods which should be uniform for the different countries.

The determination of carbon as made upon the standard samples are thus reported:

Standard.	No. 1.	No. 2.	No. 3.	No. 4.
	Per cent.	Per cent.	Per cent.	Per cent.
English committee.....	1.414	0.816	0.476	0.151
Swedish committee.....	1.450	0.840	0.500	0.170
American committee..	1.440	0.807	0.452	0.160

* *Journal American Chemical Society*, XV., p. 449.

The English and Swedish committees have not yet selected the method to be adopted as standard in carbon determinations, but the American committee have rendered their report suggesting certain modifications in the use of solvents for the iron and the separation of the total carbon.

The use of the double chloride of copper and potassium, as a solvent for iron, is recommended in place of the double salt of chloride of copper and ammonium, owing to the great difficulty in obtaining the latter salt free from pyridin and other tarry products.

Of the many methods used to obtain the amount of carbon from the iron, the following few are selected to indicate not only the variety of the processes, but a gradual improvement by combination of different methods:

Berzelius (*Annalen der Physik und Chemie*, 1838,) first suggested that the iron or steel be finely pulverized and then ignited in a current of oxygen and the resulting CO_2 weighed.

Regnault (*Annales de Chemie et de Physique*, 1839, p. 107) made use of combustion of the powdered iron with chromate of lead and chlorate of potash and the amount of CO_2 weighed.

Berzelius, however, in 1840, separated the carbon from the iron by dissolving the latter in copper chloride and igniting the carbon in oxygen (*Journal für Prak. Chemie*, 1840, p. 247).

From this period, the methods for total carbon can be included in two general classes:

First Class.—Combustion of the carbon in the powdered iron directly.

Second Class.—Separation of the carbon from the iron by chemical means and combustion of the carbon.

Deville and Wöhler (*Zeitschrift für Analytishe Chemie*, VIII., p. 401) describe processes by which the iron can be separated from the carbon, by volatilization of the iron with chlorine or hydrochloric acid gas, and combustion of the remaining carbon.

With the exception of a method described by Gmelin (*Oestreicher Zeitschrift für Berg und Hüttenwesen*, 1883, p. 392), by

which the powdered iron is treated directly with CrO_3 and H_2SO_4 and the carbon oxidized to CO_2, the methods of the First Class, above given, are no longer used.

Second Class.—These methods give better results in general practice, and nearly all the advances and improvements have been made in this direction.

Ullgren (*Annal. de Chem. und Phar.*, 124, p. 59) dissolved the iron with solution of copper sulphate and oxidized the carbon to CO_2 by heating with CrO_3 and H_2SO_4.

Eggertz (*Dingler's Polytechnishes Journal*, 170, p. 350) dissolved the iron with bromine or iodine, and the separated carbon was ignited with chromate of potash.

Langley (*American Chemist*, VI., p. 265) modified Ullgren's method by ignition of the carbon in oxygen after solution of the iron by copper sulphate.

Richter dissolved the iron with chloride of copper and potassium and burned the carbon in oxygen.

Weyl and Binks dissolved the iron in dilute HCl passing an electric current at the same time and ignited the carbon in oxygen (*Annalen der Physik und Chemie*, 114, p. 507).

Parry dissolved the iron in solution of copper sulphate, the carbon burned, mixed with CuO, in vacuo and the volume of CO_2 measured (*Chemical News*, 25, p. 301).

Eggertz' method for combined carbon (*Chemical News*, VII., p. 254), in which the iron was dissolved in nitric acid and the amount of carbon (combined) determined by color of the solution found.

McCreath and Pearse dissolved the iron with chloride of copper and ammonium and combustion of the residue (*Engineering and Mining Journal*, 21, p. 151).

Boussingault (*Dingler's Polytechnisches Journal*, 197, p. 25) decomposed with mercuric chloride and oxidized the carbon to CO_2.

Wiborgh (*Dingler's Polytechnisches Journal*, 265, p. 502) dissolved the iron with solution of copper sulphate, oxidized the carbon

by heating with $CrO_3 + H_2SO_4$, and measuring the volume of CO_2 formed.

Experience has shown that the methods of Ullgren, Langley, Richter, and Wiborgh give the best results for the total amount of carbon in iron, and that the Eggertz method for combined carbon in steel can be relied upon as the best for the purpose.

The determination of total carbon, as made in my laboratory, is either by the Ullgren or Langley methods, somewhat modified. The Ullgren method is thus performed: Six grammes of the iron, in fine turnings, are transferred to a No. 3 beaker and 100 cubic centimeters of a solution of copper sulphate* (1 to 5) added, the solution being first rendered neutral by a few drops of a very dilute solution of potassic hydrate. Digest at a gentle heat until all the iron is dissolved (no smell of hydrocarbon given off), add 100 cubic centimeters $CuCl_2$ solution (1 to 2) and 75 cubic centimeters HCl (specific gravity, 1.2) and warm until the metallic copper is dissolved. Filter upon an asbestos filter, washing first with dilute HCl, and finally with water until no reaction for HCl is obtainable with a drop of $AgNO_3$ solution. Transfer the asbestos filter containing the carbon to the flask A, Fig. 1, not using over 25 cubic centimeters H_2O in the operation. Add 10 grammes CrO_3, and in the delivery flask place 50 cubic centimeters concentrated H_2SO_4, and connect the flask with the system of U tubes.

B contains water sufficient to cover the neck of the U tube, and is made slightly acid with H_2SO_4.

C and D contain granulated $CaCl_2$ free from CaO.

E and F contain soda lime, medium granulated, and are carefully weighed before use.

G contains granulated $CaCl_2$. Allow the sulphuric acid in the delivery tube to enter flask A and close the stop-cock. Warm the contents of the flask gradually to boiling, and when no more gas passes through B open the side stop-cock of flask A and con-

*Copper chloride and HCl can be substituted as recommended by American Committee on Standard Methods.

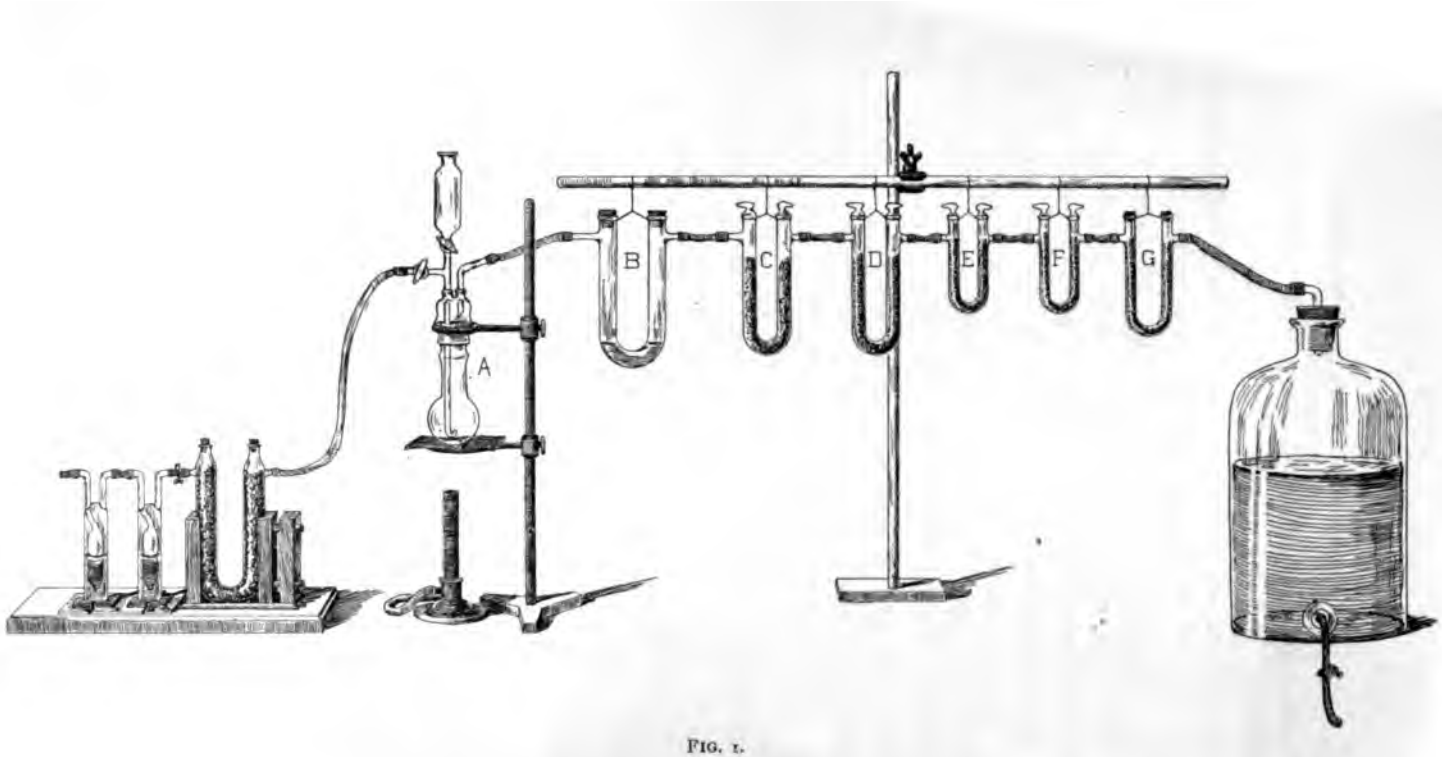

FIG. 1.

nect with the Trauber drying apparatus. The aspirator is connected with G, and air is slowly aspirated through the entire apparatus. Continue this until about five litres of air have been aspirated.

After 20 minutes weigh the tubes E and F; the increase of weight represents the CO_2 produced by the oxidation of the carbon.

Thus, 6 grammes of cast iron taken:

Tubes E and F + CO_2	65.621
Tubes E and F	65.002
CO_2	.619

$$CO_2 : C :: .619 : \times = .171.$$

$$\frac{.171 \times 100}{6} = 3.18 \text{ per cent. C.}$$

The carbon in cast iron being generally a mixture of combined and graphitic carbon, it is essential to determine the graphitic carbon, and this amount being subtracted from the total carbon gives the combined carbon. In steels where the carbon is all combined the color test of Eggertz suffices. The graphite is thus determined:

Add 50 cubic centimeters HCl (specific gravity 1.1) to 6 grammes of cast iron or 10 grammes of steel in a No. 3 beaker; warm gently until the iron is all dissolved, bring to boiling temperature for five minutes, allow the graphite to settle, and decant the supernatant liquid upon an asbestos filter; wash by decantation four times with hot water and treat residue in beaker with 25 cubic centimeters solution of potassic hydrate (specific gravity 1.1) and boil. Transfer to the asbestos filter, wash thoroughly with boiling water, then with alcohol and ether, and transfer the asbestos filter to the flask A, Fig. 1, and oxidize the carbon to CO_2 with CrO_3 and H_2SO_4, as in the process previously given for total carbon.

Thus, 6 grammes of iron taken:

Tubes E and F + CO_2	= 66.053 grammes.
Tubes E and F	= 65.621 grammes.
CO_2	= 0.432 grammes.

C = .1178 grammes.

Graphitic carbon..... = 1.96 per cent.

Combined carbon..... = 1.22 per cent.

Total carbon..... ..... 3.18 per cent.

METHOD OF LANGLEY MODIFIED.

In this process the sample is treated in the same manner for solution of the iron as described for total carbon in the Ullgren method. After the carbon has been thoroughly washed upon the asbestos filter, it is dried and transferred to a porcelain boat which is placed inside of a combustion tube in the furnace C, Fig. 2.

The tube D connected with the combustion tube contains granulated $CaCl_2$, and E and F soda lime; another tube G containing $CaCl_2$ (not shown in the figure) is also used. Oxygen under pressure in the tank A is allowed to pass slowly through the Trauber drying apparatus, which removes all moisture and CO_2, into the combustion tube and through the tubes D, E, F, and G.

Heat is gradually turned on in the furnace and increased until the carbon is completely burned to CO_2. Turn off the heat, disconnect the oxygen tank and slowly aspirate air through the apparatus by means of an aspirator (see Fig. 1).

After cooling 30 minutes weigh the tubes E and F and calculate the results as given previously.

It will be noticed that no Liebig's potash bulbs are used. *I* have obtained better results by the use of soda lime in U tubes than by the potash bulbs, and in general practice they will be found much more convenient and less liable to variation in weight.

The use of the double chloride of copper and ammonium as a solvent for the iron has been quite general in this country. The American Committee on Standard Methods of Iron Analyses found that, contrary to the usual practice, this solvent must not be neutral, but must be rendered strongly acid with from 5 to 10 per cent. of its volume of strong hydrochloric acid (*Journal of the American Chemical Society*, Vol. XV., p. 449).

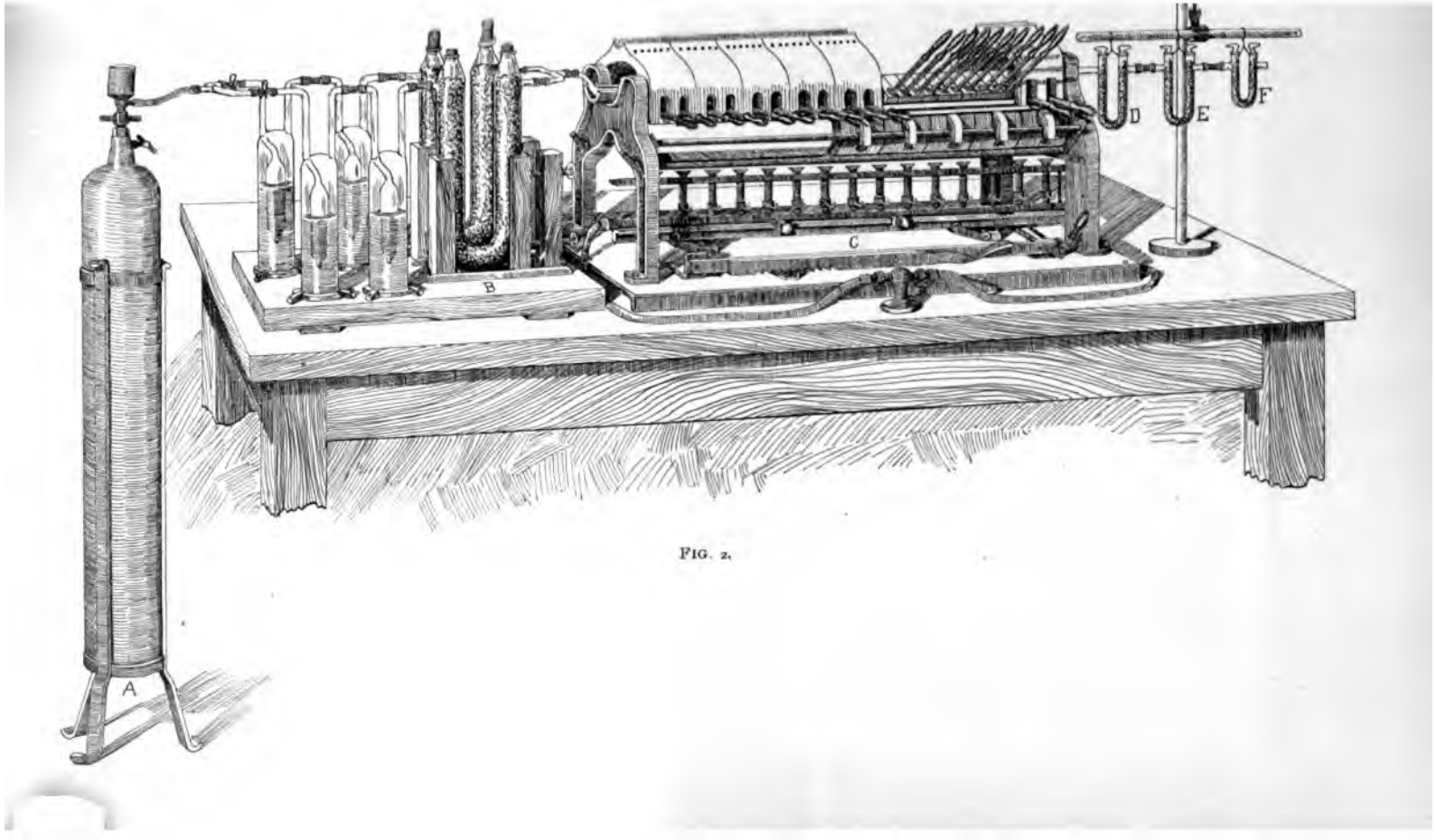

FIG. 2.

T. M. Drown in his report to the committee describes his process as follows: "Three grammes of the steel were treated with 200 cubic centimeters of a solution of copper potassium chloride (300 grammes to the litre) and 15 cubic centimeters of hydrochloric acid (specific gravity 1.2). After complete solution of the iron the carbon was filtered off on an asbestos-lined platinum boat, thoroughly washed with hydrochloric acid, and then with water until the washings gave no reaction with silver nitrate. After drying, the boat was put into a porcelain tube and the carbon burned in a current of oxygen." This is a modification of Richter's process.

There does not appear to be much choice in the method of the combustion of the carbon. Some chemists prefer oxidation with $CrO_3 + H_2SO_4$, and others ignition in a current of oxygen gas.

For rapidity of execution and simplicity of apparatus (Fig. 1) I prefer the former.

Wiborgh's method (*Journal of the Society of Chemical Industry*, VI., p. 748), in which the CO_2 is measured instead of being weighed, consists as follows: The apparatus required is shown in Fig. 3. A test tube A, 140 millimeters long by 20 millimeters internal diameter, is surrounded by a cage of brass wire gauze, and fitted with a caoutchouc cork with two perforations. Through one perforation passes the narrow end of the stop-cock funnel B, which should project for about 15 to 20 millimeters beneath the cork; through the other, but not projecting beneath the stopper, passes the connecting tube D. This latter tube consists of two portions, united by India-rubber tubing; the part more remote from A and carrying the stop-cock E is bent to pass through one of the perforations of another caoutchouc stopper in the graduated tube C, the other perforation serving to connect the latter with a stop-cock funnel F.

The tube C should, for the distance of 70 millimeters downwards, have an internal diameter of 16 millimeters; it should then be widened to a bulb G, of about 25 centimeters capacity, and be

finally reduced for the remaining 200 millimeters to about 9 millimeters, this narrow portion being graduated into divisions of one-tenth, or, preferably, one-twentieth of a cubic centimeter, denoting in each case the capacity of the whole of that portion of the tube above the respective graduations. Beneath this tube is the stop-cock H, communicating by flexible tubing with the movable

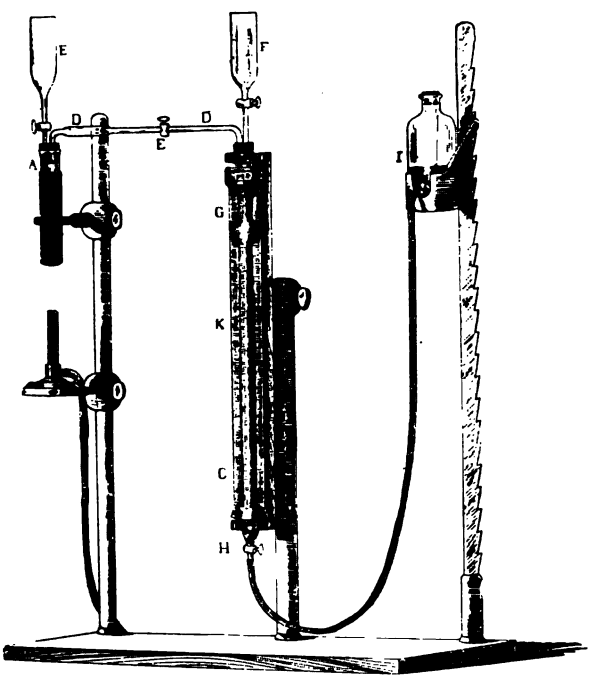

FIG. 3.

water reservoir I. The test tube A is warmed by a gas or spirit lamp, and the whole apparatus should be mounted on a suitable stand. The measuring tube is surrounded by a water jacket K to preserve an even temperature.

To conduct an analysis, 0.2 gramme of finely divided wrought iron or steel or 0.1 gramme of cast iron is introduced carefully into the test tube A, taking care that none of the filings adhere to its sides. Four cubic centimeters of a saturated solution of pure

copper sulphate are then introduced and allowed to act, with frequent stirring, during 10 minutes, unless an appreciable smell of hydrocarbon be observed, when the action must be suspended after three or four minutes. One and two-tenths grammes of crystallized chromic acid are added to the solution. Meanwhile the tube C must have been filled with water by raising the reservoir I until the liquid has risen above the bulb tube G, the remaining space up to the cock being filled by water introduced through F. The test tube is now corked and connected with the burette C.

Eight centimeters of sulphuric acid (specific gravity 1.7) are introduced drop by drop into A through B, the cock of the latter is closed, that marked E opened, and the liquid in the test tube gradually raised to boiling, the pressure having been diminished by previously lowering the water reservoir I. After 10 minutes' boiling, during which the reservoir has been still further lowered, if necessary, to maintain the diminished pressure, the tube is cooled somewhat, and, together with the connecting tube D, is carefully filled with water introduced through B. The cock E is then closed and the total volume of air and carbon dioxide read off after leveling with the reservoir.

I is then once more lowered and the cock H closed in order to draw in a quantity of a 10 per cent. potassic hydrate solution through F. After the carbon dioxide has been completely absorbed, H is reopened, the liquid leveled again and a reading of the residual air is taken.

The difference between the two readings will be the volume of carbon dioxide evolved from the carbon in the iron.

Evidently if 0.2 gramme of substance were used, each cubic centimeter of CO_2 will correspond to 0.253 per cent. of C, and the factor 0.253 multiplied by the number of cubic centimeters of gas should give a direct reading of the percentage of carbon.

But this is not quite correct, since a certain quantity of CO_2 (to be found by experiment) is absorbed by the water in the tube. By treating pure anhydrous sodium carbonate in the apparatus instead

of iron and comparing the actual with the theoretical yield of carbon dioxide the factor may be corrected.

Thus the true factor was found to be 0.28, and this was universally correct for cast irons; but for wrought irons or steels, which contain less carbon, it should be 0.29.

When 0.1 gramme of iron is used the factor must of course be doubled.

Where the temperature of the operation differs much from the normal 18 degrees, correction must be made by multiplying or dividing by $(1 + 0.00367 \times t)$, where t is the variation in temperature, according as the solution is cooler or warmer than the normal.

This process is expeditious, and a very delicate measurement of the CO_2 can be obtained thus:

One-twentieth cubic centimeter of CO_2 from 0.2 gramme of iron represents 0.014 per cent. of carbon, but weighs only 0.0001 gramme.

G. Lunge (*Stahl und Eisen*, 13, p. 655) gives this process the preference where small quantities of carbon are to be determined in cast irons.

DETERMINATION OF COMBINED CARBON IN STEEL. EGGERTZ' METHOD.

This method depends upon the color given to nitric acid (specific gravity 1.2) when steel is dissolved therein; the carbon present producing a light brown or dark brown coloration to the liquid in proportion as the carbon is in small or large amounts. The apparatus, Fig. 4, is well arranged for this test. It consists of a series of graduated tubes, of white glass, each 27.5 cubic meters long, 15 millimeters in diameter, and graduated to hold 30 cubic centimeters divided in one-fifth cubic centimeters. The back plate of the apparatus is of white porcelain, 23.5 cubic meters wide, 27 cubic meters high, and 3 millimeters thick, and I have found it much better than the various cameras to obtain correct comparisons of colors of solutions in the different tubes. Three standard steels are required, one containing 1.000 per cent. combined carbon, for tool steels, etc., one containing .400 per cent. carbon, for tires, rails, etc., and 0.200 per cent. carbon, for soft

steels; these percentages of carbon having been very accurately determined by combustion.

The process is as follows: .200 gramme of the standard steel is transferred to one of the graduated tubes, 4 cubic centimeters of

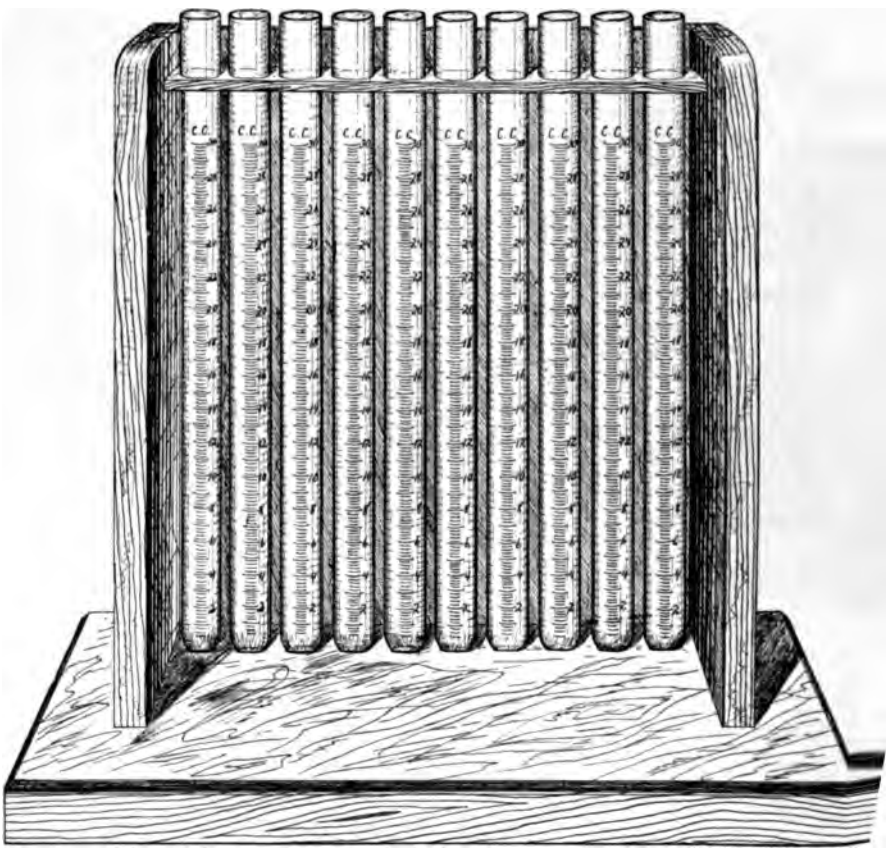

FIG. 4.

nitric acid (specific gravity 1.20) added, and the tube placed in cold water to prevent too energetic action of the acid. After a few minutes' interval the tube is placed in warm water, and the latter gradually raised to the boiling point and maintained at that temperature about 20 minutes. The sample of steel, in which the

amount of carbon is unknown, is treated in a similar manner, using the same amount of steel and acid.

Suppose the standard steel contains 0.84 per cent. of carbon,* the solution in the tube is diluted with water to 16.8 cubic centimeters. Each cubic centimeter therefore contains 0.0001 gramme of carbon. Suppose that upon dilution of the test sample solution to 14 cubic centimeters, and placing the two tubes side by side in the frame (Fig. 4), that the test sample is somewhat stronger in color than the standard sample; upon diluting it, however, to 15 cubic centimeters it is slightly lighter in color. This would indicate that the unknown or test sample contains more than .70 per cent. (.1 × $\frac{14}{15}$) of carbon, but less than 0.75 per cent. (.1 × $\frac{15}{15}$). The steel can thus be assumed to contain .73 per cent. carbon.

The use of Eggertz' color test for combined carbon requires that steels should have been subjected to similar physical treatment to that to which the standard steels had been subjected in order to secure accurate results. A steel shows less carbon, by color, when hardened than when unhardened, and less unannealed than when annealed. Several modifications of the process have been submitted by various chemists, but they offer no special advantages. Stead (*Chemical News*, 47, p. 285) renders the nitric acid solution of the steel alkaline with NaOH, which dissolves the carbon, producing a solution about 2½ times stronger in color than the solution in nitric acid. The precipitated iron oxide is filtered off, and a measured quantity of the colored filtrate is transferred to a Stead's chromometer and the color compared with a standard steel under similar conditions. Except where the carbon is present in minute quantity only is this process of any advantage over the Eggertz method.

The following references have been selected as of value upon this subject:

A. H. Elliott's modification of Rogers' process (*Journal of the Chemical Society*, May, 1869).

* Trolius.

"Determination of Combined Carbon in Steel by the Colorimetric Method," by J. Blodget Britton (*Chemical News*, XXVI., p. 139).

"On the Estimation of Carbon in Pig-Iron," by Charles H. Pierse (*Chemical News*, XXVIII., p. 199).

"Colorimetric Carbon Estimation," by Fred P. Sharpless (*Journal of Analytical Chemistry*, II., p. 55).

"A Funnel for Filtering Carbon," by Thomas M. Drown (*Journal of Analytical Chemistry*, II., p. 330).

"Determination of Carbon in the Irons of Commerce," by L. Blum (*Chemical News*, LX., p. 167).

"Determination of Carbon in Iron and Steel," by L. L. de Konick (*Zietschrift fur Analytische Chemie*, 1888, p. 463).

"A New Form of Apparatus for Determination of Carbon in Steels by Color," C. H. Risdale (*Journal of the Society of Chemical Industry*, V., p. 583).

"International Standards for the Analysis of Iron and Steel" (*Journal of Analytical Chemistry*, IV., p. 402).

"Notes on Carbon in Experimental Standards," by P. W. Shimer (*Journal of Analytical Chemistry*, IV., p. 129).

"The Determination of Carbon in Steel," A. A. Blair (*Journal of Analytical Chemistry*, V., p. 121).

"Researches on the Carbon of White Cast Iron," Isherwood (*Engineer*, XLIV., p. 461).

"Determination of Combined Carbon in Cast Iron and Steel," Townsend (*Proceedings of the Engineers' Club*, Philadelphia, Pa., II., p. 31).

"Determination of Carbon in Iron and Steel," Zabudsky (*Ber. Chem. Ges.*, XVI, p. 2318).

"The Colorimetric Determination of Combined Carbon in Steel," Alfred E. Hunt (*Transactions of the American Institute of Mining Engineers*, XII., p. 303).

"Apparatus for the Determination of Carbon in Iron and Steel by Measurement of the Evolved CO_2," Reinhardt (*Stahl und Eisen*, XII., p. 648).

"The Determination of Carbon in Iron and Steel," C. B. Dudley and F. N. Pease (*The American Engineer and Railroad Journal*, LXVII., p. 347).

"A Method for the Determination of Carbon in Steel," Frank Julian (*Journal of Analytical Chemistry*, V., p. 162).

A CHEMICAL CURIOSITY.

CALCIUM CARBIDE. Among the various uses to which electricity has been put, since its cheap production by the modern "dynamo" has been secured, is the reduction of metallic ores or compounds in one or another form of the "electric furnace."

The production of alluminum on a large commercial scale is the oldest and best known of these.

There are, however, several cases in which the separation of the single element is not secured even in the electric furnace, but in which the element desired, while parting with its former companions, insists upon a substitute, and takes the same from the carbon electrodes or lining of the furnace, or from carbon mixed with it.

This is the case in the manufacture of "carborundum," which is a compound of silicon and carbon, formed by heating silica and carbon powder in an electric furnace. This compound has reached a large commercial application, by reason of its extreme hardness, which makes it a very superior substitute for emery or corundum, as a cutting and polishing material.

The latest development in this direction, however, is seen in the calcium carbide, which is prepared by heating in an electric furnace a mixture of lime and coal dust.

The metallic calcium liberated by the action goes at once into combination with carbon to form a carbide, which is a mineral body of remarkable properties. In appearance, when in masses, it somewhat resembles the mineral serpentine, being of a greenish gray color and crystalline fracture, with a luster like feldspar. If a few drops of water are thrown on this mass of seeming rock, gas is given off, which, if ignited, burns with a brilliant flame; and, by continuing, from time to time, to sprinkle the rock with water, it will be made to blaze continuously as though it was being sprinkled with some very volatile and inflammable oil.

If a fragment of the mineral is thrown into a glass of water, a rapid evolution of gas results, which may be ignited, and will continue to burn until the mineral is exhausted.

The cause of these actions is that the calcium carbide in contact with water forms calcium oxide and acetylene gas, the oxygen of the water combining with the calcium to form calcic oxide, or lime, and the hydrogen of the water combining with the carbon to form acetylene.

It is proposed to use this calcium carbide for local gas machines. A charge of the mineral is placed in a closed vessel into which a regulated supply of water is admitted. A little water entering forms a quantity of gas whose pressure shuts off the water; but, as the gas is used up, more water comes in to renew the supply.

What may be the commercial value of this material we are not prepared to say, but it is certainly a great chemical curiosity.

H. M.

EXPERIMENTAL DETERMINATION OF THE QUICKNESS OF ACTION OF A SHAFT GOVERNOR, AND THEORETICAL CONSIDERATION OF THE INFLUENCE OF AN INERTIA WEIGHT.

BY PROF. D. S. JACOBUS.*

THE experiments to determine the quickness of action were made on a Ball & Wood engine at the Stevens Institute of Technology. They consisted of automatically recording the spiral paths traveled over by the governor balls, as they moved from one position to another under various changes of load. These experiments show that the time to effect an adjustment of the governor from one-half load to no load is the same as from full load to no load; and that if the governor is set just at the point of "hunting," so that the springs are at the full theoretical tension, the time required to adjust from one load to another is about the same as the time required when the springs are set so that the speed of the governor is considerably below that for a correct adjustment. In other words, the governor will regulate just as quickly when the springs are set so that it is in very stable equilibrium as when set so that the governor is just at the point of unstable equilibrium

*The general method of conducting the experiments on the quickness of action was presented at the meeting of the American Association for the Advancement of Science held at Madison, Wis. The present paper is abstracted from a discussion presented by the writer at the last meeting of the American Society of Mechanical Engineers at Montreal, Canada, on a paper by Mr. Albert K. Mansfield, entitled "Notes on the Theory of Shaft Governors," which will appear in Volume XV. of the *Transactions*.

A theoretical consideration of the action of an inertia weight shows that it may be attached to a governor in such a way as to retard instead of accelerate the speed of adjustment, notwithstanding

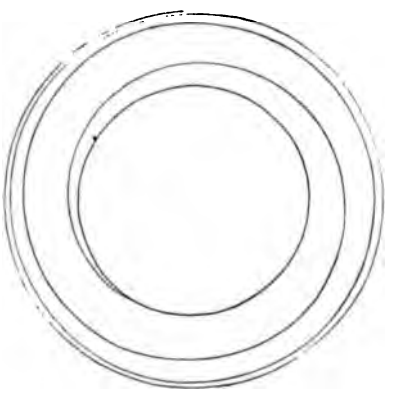

Fig. 1.—Springs at full theoretical tension. Revolutions 285 per minute. Dash-pot removed and governor in unstable equilibrium.

the fact that the force which a change of velocity tends to produce in the weight is in the proper direction to effect an adjustment.

In the actual experiments the spirals are not taken directly from the governor balls, but they are taken from the center of the

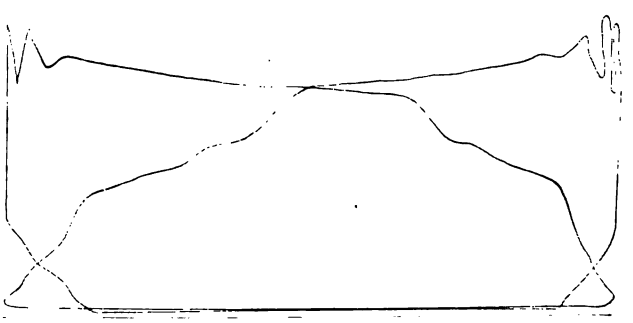

FIG. 2.—Indicator cards taken before removing the load and tracing the spiral shown in Fig. 1. Scale = 40.

valve eccentric, which, being moved by the governor itself, represents the movement of the governor after proper corrections are ². Figures 1, 3, 5, 7, and 9 show these spirals.

The indicator cards shown in Figs. 2, 4, 6, 8, and 10 represent the steam distribution before and after the load is thrown

FIG. 3.—Tension of springs adjusted so that the governor is just at the point of unstable equilibrium. No dash-pot. Revolutions 265 per minute.

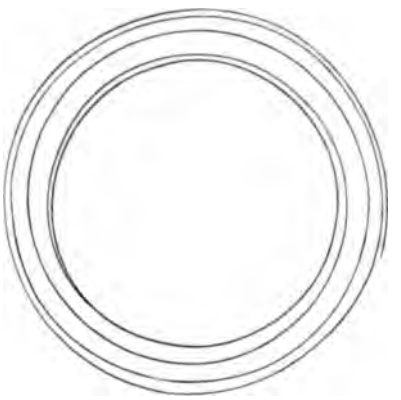

FIG. 5.—Adjustment of governor same as in Fig. 3, with less variation of load than that corresponding to Fig. 3. See indicator cards Nos. 4 and 6.

off, and Fig. 11, the average indicator card after throwing off the load. By counting up the number of the coils of the spirals in Figs. 3, 5, etc., we obtain the exact number of revolutions required for the

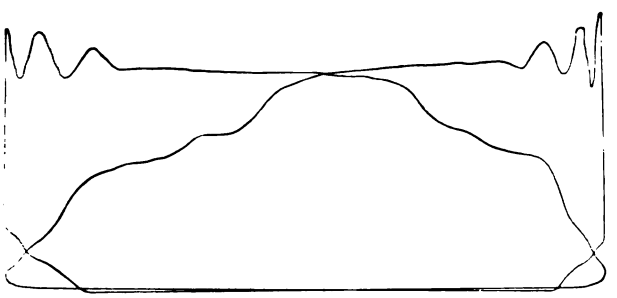

FIG. 4.—Indicator cards taken before removing the load and tracing the spiral shown in Fig. 2.

governor to move from one position to the other, and in this way we find the amount of time required to make an adjustment.

There were two sets of curves obtained in the experiments, one with a dash-pot on, and one with the dash-pot off. For the present

discussion we will only consider those obtained with the dash-pot removed, which are those represented in the figures. The curves show that the time to effect the adjustment is accomplished in all cases in about 3½ revolutions.

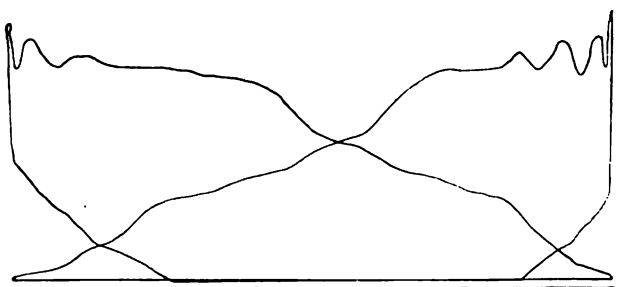

FIG. 6.—Indicator cards taken before removing the load and tracing the spiral shown in Fig. 5.

Let us now consider the so-called inertia effect. It may be demonstrated that if we add an inertia weight, or an inertia wheel, in the way that it is represented in the last figure of Mr. Mansfield's

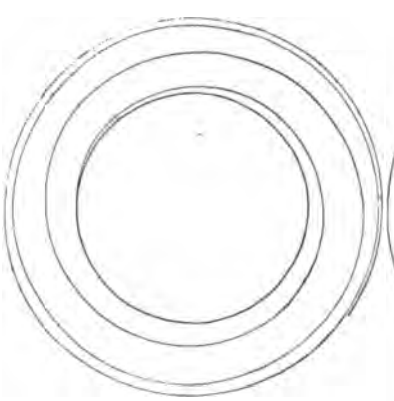

FIG. 7.—Tension of springs adjusted so that governor is in stable equilibrium. No dash-pot. Revolutions 245 per minute.

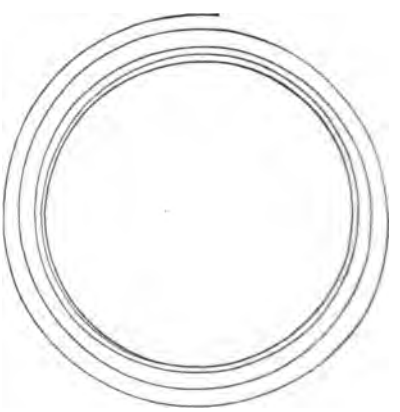

FIG. 9.—Adjustment of governor same as in Fig. 7, with less variation of load than that corresponding to Fig. 7. See indicator cards Figs. 8 and 10.

paper (see Fig. 12), we may retard, instead of accelerate, the action of the governor. Mr. Mansfield has stated that for a large flywheel

the inertia weight produces very little accelerating effect, whereas it may be readily demonstrated that if wrongly applied it will have a retarding action, so that a governor with an inertia weight would require a longer time to move from one position of adjustment to another than it would with the weight removed.

No experiments were made on the inertia weight, but the action of the inertia weight may be readily solved in an approximate way, in which all the errors involved will be against the fact finally demonstrated, which is that an inertia weight may be put on so as to retard the action of the governor, notwithstanding the fact that

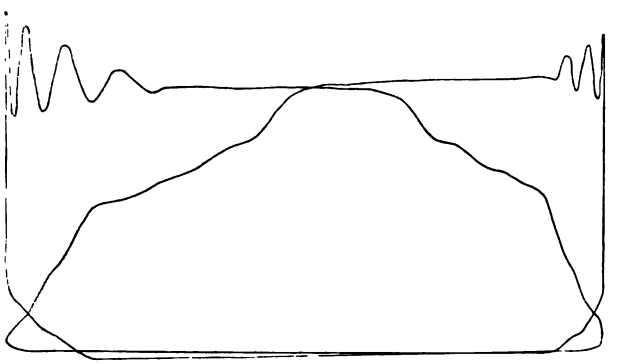

FIG. 8.—Indicator cards taken before removing the lead and tracing the spiral shown in Fig. 7.

the force which a change of velocity tends to produce in it is in the proper direction to effect an adjustment.

Let us consider the case where the inertia weight is a loose flywheel, as represented in Fig. 12. Assume that the loose flywheel had 60 degrees angular movement, which conforms with cases of actual construction, and determine the amount of variation in speed that would have to take place if the loose flywheel moved through its extreme range in one, two, three, and four revolutions of the engine shaft. If moved through the entire range in one revolution, the speed of the flywheel would have to vary 33⅓ per cent. in order that the governor should move through the extreme of its range of 60 degrees. This is on the assumption that the flywheel

is uniformly accelerated, in which case we have $\frac{2 \times 60}{360} = 33\frac{1}{3}$ per cent. If moved through the extreme range in two revolutions, the speed would have to vary $33\frac{1}{3} \div 2 = 17$ per cent. In three rev-

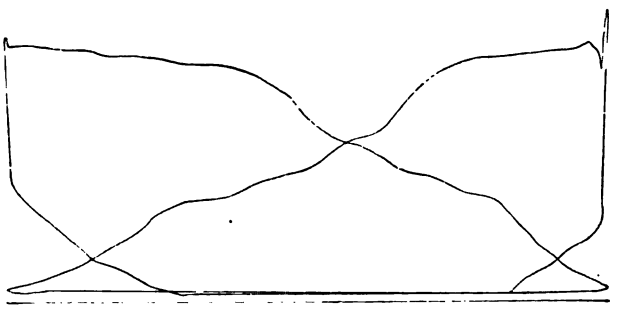

FIG. 10.—Indicator cards taken before removing the load and tracing the spiral shown in Fig. 9.

olutions it would have to vary 11 per cent., and in four revolutions 8 per cent.

Taking the case of the Ball & Wood engine, in which these diagrams were obtained, we can readily determine how much an inertia wheel, placed loosely on the shaft, would move backwards

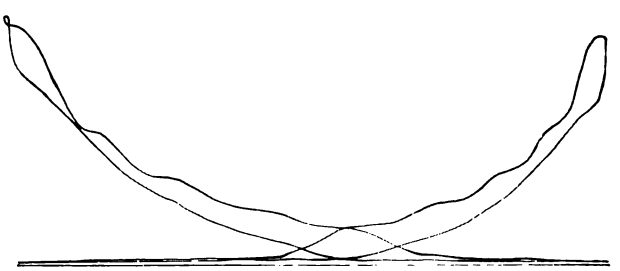

FIG. 11.—Average indicator cards taken after removing the load from the engine and tracing the spirals represented in the figures. Scale of all cards = 40 pounds per inch.

for each revolution if the load driven by the engine is suddenly removed. Assuming that the whole effect of the steam acts on the engine after the load is removed, we may determine the minimum time required to move the inertia wheel through a given

angle, or the maximum angle that the inertia wheel will move through per revolution of the flywheel shaft.

If the inertia wheel were used in the ordinary way the resistance of the valve would tend to increase the time required to effect an adjustment. The point of cut-off would also be earlier at each successive stroke after the load was thrown off, which will also increase the time of action, so that it would be greater than the minimum time determined by assuming the entire effort of the steam to act on the flywheel as already described.

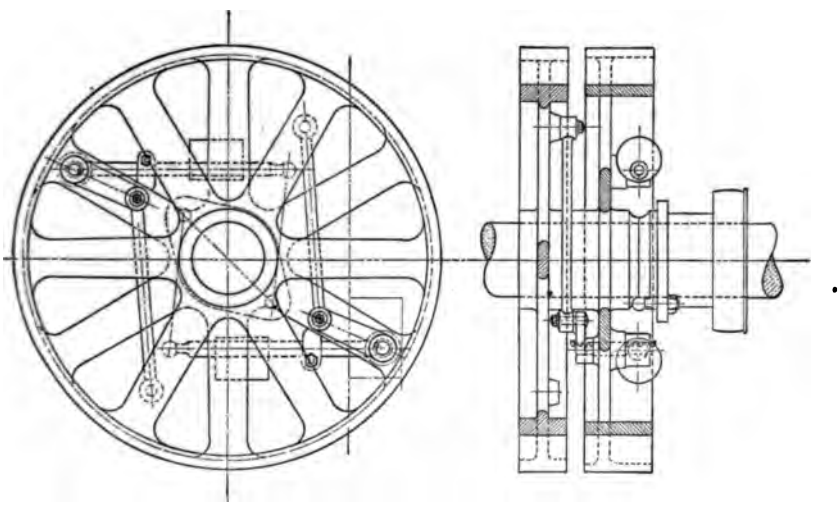

FIG. 12.

In the case of the Ball & Wood engine there are two flywheels, each 5 feet in diameter, and their combined weight is equivalent to about 1,600 pounds at the rim. The cylinder is 10x11 inches, and the engine is rated at 50 horse-power, at 300 revolutions per minute. If, while running at 50 horse-power, the load is suddenly removed, the gain in speed per revolution, as calculated by Rankine's formula, and assuming no diminution in the indicator cards, is 1.8 per cent. The movement of a loose flywheel for this variation of speed would be $0.018 \times 360 \div 2 = 3.2$ degrees. For two revolutions the

movement would be $3.2 \times 4 = 13$ degrees. For three revolutions the movement would be $3.2 \times 9 = 29$ degrees; and for four revolutions, $3.2 \times 16 = 51$ degrees. Therefore, if the entire power of the engine were employed to accelerate the flywheel, the amount of movement of the loose wheel would be 51 degrees in four revolutions.

We have not, as already stated, considered the effect of the action of the valve mechanism in retarding the velocity of the loose wheel, or of the diminution of acceleration of the flywheel on account of the reduction of work in the cylinder at each successive revolution after the load is suddenly removed. Both of these effects would tend to retard the quickness of action of the loose wheel so that a less angle would be moved through than is indicated by the calculations.

For $3\frac{1}{2}$ revolutions the maximum angle that the loose wheel could move through is $3.2 \times 3.5 \times 3.5 = 39$ degrees. The experiments demonstrated that the governor moved over the extreme range in $3\frac{1}{2}$ revolutions, so that if an inertia wheel having an angular movement of over 39 degrees were used in connection with the governor it would retard instead of accelerate its action.

The writer does not wish to be understood as speaking against the use of the so-called inertia governor, because, if rightly applied, it may hasten the adjustment, and, combined with the dash-pot to prevent overtravel, it may be made to combine quickness of action, with stability and close adjustment of speed. If a dash-pot is placed on a governor which has but little power, it retards the action considerably. An inertia weight having a small angular advance and producing a powerful action of the governor will produce the best results, and this should be borne in mind in designing a governor.

THE MANISMAN PROCESS FOR ROLLING STEEL TUBES.

THE most remarkable discovery in mechanics since that involved in the Giffard injector is presented in the Manisman process for rolling steel tubes.

By this process a hot steel billet is passed in between two conical rolls set with their axes at a small angle to each other, and comes out on the other side as a tube with uniform walls, without the use of a mandril or anything else to make the central opening.

This process in fact realizes the familiar Hibernian description of the means of making a cannon: "You take a hole and cast metal round it."

In the Manisman process it seems as if a hole were taken to serve as a mandril and the steel were rolled on it into a tube.

So far as the process admits of a popular explanation, the following would seem to be the best that can be given.

If an uniform bar of steel be stretched lengthwise it will gradually thin down, by the yielding of the surface layers, until it breaks.

If, however, the bar be much harder on its surface than in its interior, then the interior layers or substance will yield first, developing a cavity along the axis of the bar.

It may be supposed that the first effect of the rolls on the hot billet is to harden its surface, and then the elongating strain causes a parting of the interior portions and the formation of a tube. Tubes made in this way, from the size of a knitting needle to a diameter of 10 inches, were exhibited at Chicago last year.

If a billet is drawn down beforehand at its ends and at one or more points in its length, to the diameter which it would have after passing the rolls, the result will be to produce a tube closed at both ends and wherever else the billet was drawn down.

The tube in this case must be vacuous except so far as it may contain gases extracted from the steel during the rolling process.

H. M.

EXTRACTS FROM THE ENGINEERING PRESS.

SILVER MINING IN SOUTH AMERICA.—"The silver ore deposits of the famous district of Cerro de Pasco, in South America, were discovered in 1630 by Huari-Capcha, an Indian shepherd, and in the early part of its history the district yielded enormous riches. The records from 1784 to 1846, excluding five years, 1821–25, during which civil war prevailed, show a product of 2,323,526 pounds of silver, and the value of the total product since the discovery may be estimated at about $565,000,000.

"The town of Cerro de Pasco is in the province of the same name, in the department of Junin, Peru, 14,250 feet above sea level. The nearest railway station is on the line of the Callao and Cerro de Pasco Railroad, at a distance of about three days' travel on horseback. The population of the town numbers about 6,000, mostly native Indians. The mines are mainly located in the immediate neighborhood of the town, and partly even under the principal streets, being distributed in several very large open cuts, 250 to 350 feet deep, called tajos, which extend in a nearly direct north and south line west of the town.

"The claims in the tajos are 30 by 60 varas (1 vara = 33 inches) in size. Those not located in the tajos are 100 by 200 varas. The close proximity of the claims and the general disorder underground are causes of frequent quarrels and litigation. At present but little ore is extracted by open cuts, most of the mines being worked by means of small, steep, and irregular inclines, of which one entrance sometimes serves for two or three different claims.

"The ores are extracted by means of picks, and then broken with sledges to such a size that they can be placed in large leather sacks holding from 75 to 150 pounds each, and carried out to the dump. In places where the ground is exceptionally hard, drills and powder or dynamite are used. Hoists or whims are not used, all the ores being taken to the surface by carriers. After the ores have been

deposited on the dump, they are separated into three classes, called chancados (ores spalled to a uniform size), cernidos (sifted ores remaining on a ½ or ¾-inch screen), and llampu (the finest passing the screen). The last class contains but two marcos (1 marco = 7.5 ounces) of silver per cajon (6,000 pounds), and is rejected. The first and second classes are measured separately in rudely constructed boxes, three of which are considered as a cajon; and the ore is ready to be sold the amalgamating works, or haciendas, as they are called in Spanish.

"The ores of the district from which by far the greatest portion of silver is obtained are oxidized surface ores, called pacos, containing some silver in its native state. By long experience the miners are able to judge the quality of the ore by its appearance, though often the differences are very slight. Frequently lots of ore are purchased by the millman without any special test, he being guided alone by the appearance of the ore and his previous experience with it. Pacos, at present, vary from 4 to 8 marcos per cajon. Ores having less than 4 marcos are worthless, as 4 marcos will just pay expenses. In general, the ores sold contain from 5 to 6 marcos per cajon of silver, or, say, from 12½ to 15 ounces per ton.

"The ore is transported from mine to mill with llamas or donkeys, the former taking 100 pounds and the latter 200 to 300 pounds at a load.

* * *

"Labor at the mines is almost entirely done by native Indians, or peons, and, whenever possible, it is done by contract, so that a man can earn a little more than at day's wages, which average from 50 to 60 cents per day. One of the difficulties with the peons is their great fondness for alcoholic stimulants, which is generally indulged in toward the end of the week by consuming large quantities of chacta, a liquid distilled from the juice of the sugar-cane. Hence, but little work is done on Fridays and Saturdays.

* * *

"The present low price of silver must be a great hardship to Cerro de Pasco, which depends almost entirely on that metal for its existence. It is doubtful if any but the very best equipped mills can successfully meet the present conditions, as even in more favorable times many miners and millmen made but a precarious

living."—*Otto F. Pfordte, M. E., '86, in Cassell's Magazine, October*, 1894.

AN EXPERIMENT WITH LIGHTNING ARRESTERS ON A 3,000-VOLT ALTERNATING-CURRENT CIRCUIT.—"Lightning storms in the West, particularly among the mountains where water power abounds, have up to the present time proved a serious drawback to the successful operation of electric light and power plants. In some instances these plants are, by reason of frequent and violent electric storms, practically inoperative during the afternoons of the summer months, and now that such far-reaching progress has been made in the construction of high-potential alternating-current power-transmission apparatus, the subject of protection against lightning has become of vital importance. The ordinary devices which provide automatic circuit interrupting attachments, and which are still used with doubtful success on circuits of low potentials, had signally failed to do the work required of them on these high potential circuits, and it had become evident that something radically new was needed. During the winter of 1892 and 1893 I made a searching investigation of this subject, experimenting with disruptive discharges and various kinds and combinations of apparatus which might promise advantageous results, and since that time have spent nearly six months in the State of Colorado—a land of thunder-storms—testing the various forms of apparatus which I had designed as a possible protection against lightning, and have also made a careful study of such phenomena as presented themselves. This work was carried out with the determination to construct, if possible, some form or combination of apparatus which should practically shut out lightning discharges from the vital parts of a system, and thus greatly enhance the possibilities of electric power transmission.

"The general requirements of efficient lightning arrester apparatus are: First. To provide discharge circuits which shall operate automatically and repeatedly, and which shall with certainty avoid dynamo short circuits or interruption of the system. Second.

ovide discharge circuits, or so install them that they shall bly offer a certain path to ground for disruptive discharges erence to any other part of the system. It follows also from st, and as a matter of practical experience, that ground dis-

charge circuits should be short and straight, and that ground connections should be of the most approved construction.

* * *

"The plant selected for the trial of this apparatus was that of the San Miguel Consolidated Gold Mining Company, of Telluride, Colorado, which is equipped with a 3,000-volt alternating-current synchronous system, operating stamping mills, and furnishing current to the Telluride Electric Light Company. These points are situated among the mountains at distances varying from three to ten miles from the power-house. Three separate circuits leaving the power-house extend over a wild and rocky country, and in some places rise above timber line. In previous years every attempt to protect this plant from lightning had failed. During the summer months two horses were kept constantly saddled ready for emergencies consequent on lightning discharges, and at the motor and power-house it was common practice on the approach of a thunderstorm to lay out, ready for instant use, an extra armature coil, with all the necessary tools for handling the same. In one of the former types of arresters used in this plant 40 fuses were blown inside of 60 minutes.

* * *

"The net results of this lightning-arrester experiment are most satisfactorily summed up in the following sentence from a letter written to the author by Mr. P. N. Nunn, Electrical Engineer of the San Miguel Consolidated Gold Mining Company.

* * *

"Since putting in your non-arcing metal arresters in connection with your system of specially designed choke-coils, we have passed through the lightning season of 1893 without a particle of lightning having passed, to our knowledge, beyond the arresting apparatus, without a shut-down, without the loss of a coil, and without a single perforation of insulation."—*Alexander Jay Wurts, M. E.*, '84, *Transactions of the American Institute of Electrical Engineers.*

AUXILIARY MACHINERY OF AN OCEAN GREYHOUND.—"Of the throngs that annually surge back and forth across the Atlantic, comparatively few avail themselves of the opportunity of descend-

ing into what seem grimy depths of their temporary floating homes—the engineer's realm, where throbbing engines, fiery furnaces, and monstrous boilers unite their energies in speeding the great ship onward. They know that somewhere down below there is a maze of wonderful machinery and a small army of faithful toilers, by no means resplendent in blue cloth and brass buttons, but upon whose efforts much of their safety and comfort depends; even the venturesome ones, however, that dare penetrate into this sphere of mysterious agencies carry away with them only an inadequate idea of all that it contains. True, they have seen, in part at least, the mighty engines, towering above them, ceaselessly turning ponderous shafts; they have, mayhap, even braved the stifling atmosphere of the stokehole, where greedy mouths of endless rows of furnaces hungrily yawn for coal, fed in by half-clad men, seeming imps of darkness, with ever busy shovel.

"This is but a part, however, of what the bowels of the great ship harbor. Of what is known as the auxiliary plant of the vessel, the visitor sees little, and impressive though his trip to the lower regions may have been, his conception of the actual machinery equipment remains vague indeed. There are electric light engines and dynamos, steering gear machinery, refrigerating apparatus, hoisting engines and ventilating outfits, and pumps in endless array, mere mention of which would be a revelation to him, and whose importance, withal, is of the first order.

"Roughly speaking, these auxiliary appliances require for their operation about one-tenth of the steam supply furnished to the ship's main engines, representing the equivalent of from two to three thousand horse-power on steamers of the larger sizes."—*Henry L. Ebsen, M. E.*, '89, *in Cassier's Magazine, September*, 1894.

How Materials are Tested.—"Even a horse must show the color and character of its teeth before it is permitted to eat a new master's oats.

* * *

"When, however, products are put to trial, the testing is done in two ways: Firstly, to determine the quality and properties of the materials used; and secondly, to determine the character or resistance of the finished article made therefrom. Thus, the plates and

rivets to be used in a boiler are tested at the rolling mills where they are made, and when the boiler is complete it is tested as a whole.

"Armor-plate is first tested in the mill to determine the quality of the material, and the finished plate is subjected to the test of impact of ball or shell. Guns, again, are tested first, by testing small pieces cut from the tube and also the jacketing rings, while, when finished, they are subjected to heavy powder charges.

"Sometimes a simple test may suffice to define with absolute certainty the quality and process of manufacture of the article, although in use the material may not be at all applied to that indicated by the test—e. g., paper, in strips, tested by tension test, especially that used for bank notes.

"Enumerating the different kinds of tests, we find: 1. The tension test. 2. The compression test. 3. The transverse test. 4. The torsion test. 5. The drop test. 6. The hardness, or penetration test. 7. The abrasion test. 8. The cooking test. 9. The freezing test. 10. The absorption test.

"All of these have been fully investigated and give entirely accurate and reliable results and data of scientific value. There are a number of others, which, although giving practical results in the hands of a trained operator, have not yet been so thoroughly studied as to give numerical values or comparable data. These may be classified as: (*a*) The bending test. (*b*) The nicking test. (*c*) The flattening, or spreading test. (*d*) The shearing test. (*e*) The punching test. (*f*) The drifting test."—*Gus C. Henning, M. E.*, '76, *in Cassier's Magazine for October*, 1894.

ATHLETICS.

FOOT-BALL.

FOOT-BALL practice for the season of 1894 was begun on Wednesday, September 19, one week before college opened. The following schedule of games was arranged by Manager Carter:

Saturday, September 29, Orange Athletic Club, at Orange.
Saturday, October 6, South Orange Field Club, at South Orange.
Wednesday, October 10, New Jersey A. C., at Hoboken.
Saturday, October 13, Crescent A. C., at Bay Ridge.
Wednesday, October 17, Rutgers, at Hoboken.
Saturday, October 20, Elizabeth A. C., at Elizabeth.
Wednesday, October 24, New York University, at Hoboken.
Saturday, October 27, Lafayette, at Easton.
Saturday, November 3, Wesleyan, at Middletown.
Saturday, November 10, Rensselaer P. I., at Troy.

STEVENS *vs.* ORANGE.—The season was opened rather more favorably than was expected on Saturday, September 29, by a tie game, with the Orange Athletic Club at Orange, N J. The Stevens team had not played against even so much as a scrub; and everyone being aware of the undoubted strength of the Orange team, the result of the game was a surprise to both sides. There having been some speculation as to how the new rules would be enforced, it was gratifying to note that several attempts at mass plays were stopped by the umpire, and that punts and drop kicks were seen more than formerly.

During the first half the ball was in Stevens territory most of the time. The play, as a whole, was loose and neither side scored. In the second half Cuming made two long runs around the end, scoring a touchdown for Stevens, and Fielder did the same for Orange. Both goals were kicked, making the final score, 6—6.

The teams lined up as follows:

Stevens (6).		*Orange* (6).
Chambers	Left end	J. Kyle.
Hutchinson	Left tackle	Webb.
Lançon	Left guard	Vaughn.
Mathey	Center	Mohor.
Mayher	Right guard	Hoag.
Cuming	Right tackle	Dailey.
Schalk	Right end	Coyne, (Capt.)
Kemble, (Capt.)	Quarter-back	Brett.
Church	Left half-back	W. Kyle.
[illegible]ard	Right half-back	King.
[illegible]t	Full-back	Fielder.

The umpire was Mr. W. H. Corbin, the referee Mr. John De Hart, and the linesman Mr. W. Willet.

STEVENS *vs.* NEW JERSEY A. C.—This game, the first on the home grounds, was played on Wednesday, October 10, and was won very easily by Stevens by a score of 28—0.

The chief feature of the game was the splendid interference of Stevens, which the visitors found very difficult to break up. Several runs of 40 yards or more were made and Hamilton once made a run of 80 yards after catching the ball on the kick-off.

The teams were as follows:

Stevens (28).		*N. J. A. C.* (0).
Chambers	Left end	Devlin.
Hutchinson	Left tackle	Couch.
Mayher	Left guard	Fox.
Woodward	Center	Finelli.
Laçnon	Right guard	Vogtler.
Pope	Right tackle	Trathen.
Hamilton	Right end	Roderick.
Kemble	Quarter-back	Masterson.
Church	Left half-back	Tasmer.
Cuming	Right half-back	Barkley.
Corbett	Full-back	Evans.

Referee, Mr. Percy MacKenzie; umpire, Mr. Lowell; linesman, Mr. H. Messimer.

STEVENS *vs.* CRESCENT A. C.—Part of the Stevens team went to Brooklyn on Saturday, October 13, to play the Crescent Athletic Club. There was a pouring rain all the morning and the grounds were several inches deep with mud, but as the Crescent management insisted on the game being played, the teams wallowed for an hour or so in the mud of Eastern Park, the Crescents scoring 34 points.

STEVENS *vs.* RUTGERS.—The first game of the Middle States League was played on Wednesday, October 17, when a large number of Rutgers men came to Hoboken and saw their team get even with Stevens for their defeat of last year. Rutgers had already defeated the strong Lafayette team, and in view of the fact that two Stevens half-backs were on the list of injured, defeat for Stevens seemed inevitable. Rutgers played a quick, strong game and they easily broke into the interference of Stevens.

At 3.45 P. M. the teams lined up as follows:

Stevens (0).		*Rutgers* (20).
Hamilton	Left end	Messler.
Hutchinson	Left tackle	Scudder.
Mayher	Left guard	Carpenter.
Woodward	Center	Mills.
Lançon	Right guard	Ramsey.
Corbett	Right tackle	Dyke.
Coyne	Right end	Mason.
Kemble	Quarter-back	Denise.
Harrison	Left half-back	George Ludlow.
Cuming	Right half-back	Gabe Ludlow.
Jennings	Full-back	Parker.

The referee was Mr. Alexander, of Wesleyan, '87, the umpire Mr. Jayne, of Princeton, and the linesman Mr. Scudder, of Rutgers, '88.

At the kick-off by Stevens Rutgers secures the ball and forces it down the field by center plays, when Stevens gets it by a fumble. Rutgers gets the ball again on four downs, and forces it toward the Stevens goal by end and center plays, until George Ludlow goes through the center for the first touchdown. Parker tries for goal, but fails.

At the kick-off Stevens loses 10 yards by off-side play. Harrison and Jennings now gain 20 yards each, and Cuming 30; the ball is carried over the line, but fumbled and a touchback made by Rutgers. Cuming is forced to retire on account of a sprained shoulder, Hamilton taking his place and Chambers going to end. The ball is brought to the 25-yard line, and several small gains made, when George Ludlow gets the ball on a fumble, and is tackled by Hutchinson after a run of 60 yards. Rutgers now loses the ball on four downs on the Stevens 5-yard line. Jennings punts against a strong wind which carries the ball back of the goal line, where Scudder scores the second touchdown for Rutgers, from which Parker kicks goal. Shortly after the ball is again started time is called, and the first half ends with the score: Rutgers, 10; Stevens, 0.

Early in the second half Jennings is injured, and Mathey takes his place. In this half Rutgers makes two more touchdowns by steady center work, goal being kicked from one only. The half ends with the final score: Rutgers, 20; Stevens, 0.

This game gives Rutgers the championship.

Shortly after the Rutgers game it was decided that, in view of the fact that four half-backs, regular and substitute, were injured badly, it would be useless to attempt any more games, and the team was disbanded.

LACROSSE.

PRELIMINARY lacrosse practice was begun by Captain Corbett on Tuesday, October 23. A number of new men have been seen in the field, and the material appears to be very promising.

INSTITUTE NOTES.

BY MISTAKE, a candidate who had received a less number of votes at the annual election of the Alumni Association than Mr. De Bonnevillle had, was stated in the July number of the INDICATOR to have been declared elected Director for two years.

The officers of Stevens Alumni Association for the current year are:

President, WILLIAM HEWITT, '74; Trenton Iron Co., Trenton, N. J.

First Vice-President, HARRY DE B. PARSONS, '84; 22 William St., New York.

Second Vice-President, ADAM RIESENBERGER, '76; Stevens Institute, Hoboken, N. J.

Corresponding Secretary, PHILLIP E. RAQUÉ, '76; Times Building, New York.

Recording Secretary, J. DAY FLACK, '87; 23 Prospect St., East Orange, N. J.

Directors for two years:

HARRY VAN ATTA, '81; J. L. Mott Iron Works, Mott Haven, N. Y.

A. A. DE BONNEVILLE, 78; 95 Liberty St., New York.

Directors for one year:

WILLIAM H. SHELDON, '78; 329 Belleville Ave., Bloomfield, N. J.

JOSEPH A. MCELROY, '87; 143 Liberty St., New York.

Alumni Trustees:

F. E. IDELL, '76; Havemeyer Building, New York.

DURAND WOODMAN, '80; 80 Beaver St., New York.

PROF. COLEMAN SELLERS, E. D., recently visited McGill University at Montreal, Canada, and at the invitation of the Faculty made an extemporary address to the students.

In this address he pointed out, among other things, the importance of the modern method by which in great works the engineer outlines the work to be done, but throws the responsibility of design upon the engineering establishments that are familiar with each thing required, and contrasted it with the method of striking out a new course on his own responsibility, which generally results in costly experiments, if not in failure.

During Professor Sellers' visit, one of the principal officers of the University said to him that he would probably be interested to know that in conversation with several large manufacturers, people employing graduates from the different technical schools, he had been impressed with the favor shown to graduates of the Stevens Institute.

In more than one instance he had been told that they would prefer in all cases a graduate of Stevens rather than one from another school, not only on account of the thoroughness of their education, but from the fact that they had evidently come away from the Institute impressed with the idea that they had much yet to learn of a practical character, while particularly in regard to certain institutions their graduates had a very conceited idea as to their own fitness for work and seemed convinced that there was little left for them to learn.

AT THE JUNE MEETING of the Faculty a committee consisting of Professor Krœh and Assistant Professors Riesenberger and Graydon was appointed to ascertain the opinions of our graduates, of other mechanical engineers, and of employers of mechanical engineers, as to the utility of a knowledge of Spanish.

The committee has sent out circulars to all of the alumni whose addresses are at hand, and already a large number of replies have been received. It is too early to determine the weight of the evidence thus secured, and it is hoped that all responses will be soon sent in.

AT THE MONTREAL MEETING of the American Society of Mechanical Engineers the Stevens contingent included, Professors Webb and Jacobus, R. H. Rice, A. W. Burchard,'85; W. E. Schoenborn,'87; H. C. Meyer, Jr.,'92.

PROFESSOR BRISTOL exhibited, at the Brooklyn meeting of the American Association for the Advancement of Science, a working model of his recording thermometer for closed spaces. By this simple apparatus, the temperature within an oven, flue, or other space practically inaccessible at the time when it is important that the temperature be known, is indicated in the office, engine-room, or any other convenient place; and the changes in temperature are continuously recorded.

Engineering of August 24, 1894, published an article by President Morton, descriptive of the pneumatic pyrometer and the principles governing its action; and a reprint of the article appeared in the *Journal* of the Society of Chemical Industry of September 29.

THE OFFICERS of Stevens classes and societies for the current year, as determined by recent elections, are as follows:

'95.	'96.
President, W. H. CORBETT.	President, B. C. CLARK.
Vice-President, E. C. SCHMIDT.	Vice-President, CHAPIN.
Secretary, F. W. WALKER.	Secretary, H. GUTTIN.
Treasurer, E. M. HARRISON.	Treasurer, EVERETSZ.
Historian, E. M. ROBINSON.	Historian, C. H. HUNT.
Senators, E. KEMBLE, D. D. BARNUM, M. E. CRAFT, A. SUMNER.	*Link* Editor, B. C. CLARK, in place of F. R. HARRIS, resigned.
Indicator Editors, B. W. JACKSON and F. K. VREELAND.	

'97.

President, W. E. MALLALIEU.
Vice-President, J. CROMWELL.
Secretary, R. C. MESSIMER.
Treasurer, H. ANDERSON.
Foot-ball Captain, G. HUTCHINS.
Foot-ball Manager, A. M. ORR, Jr.
Cane Spree Committee, J. HUNTER, LENT, and G. D. WILLIAMSON

'98.

President, R. C. POST.
Vice-President, F. D. KENNEDY.
Secretary, C. R. HEMINGER.
Treasurer, W. B. RITTENHOUSE.
Foot-ball Captain, R. MCLAIN.

THE ENGINEERING SOCIETY.

President, F. V. LAWRENCE, '95.
Vice-President, H. H. MAXFIELD, '95.
Secretary, A. F. GANZ, '95.
Treasurer, F. R. VREELAND, '95.
Executive Committee, P. ALLAN, '95, Chairman; C. A. GREENIDGE, '95; A. R. HAMILTON, '95.
Membership Committee, D. D. BARNUM, '95; W. H. CORBETT, '95; M. E. CRAFT, '95.

GLEE CLUB.

President, H. C. MESSIMER, '96.
Secretary and Treasurer, E. M. HARRISON, '95.
Temporary Leader, H. C. MESSIMER, '96.

BANJO CLUB.

President, S. COOPER, '95.
Secretary and Treasurer, H. HARDIE, '96.
Leader, D. BARNUM, '95.
Assistant Leader, R. C. MESSIMER, '97.

MANDOLIN CLUB.

President, S. COOPER, '95.
Leader, G. KOLLSTEDE, '96.
Secretary and Treasurer, E. D. MATHEY, '97.

THE STEVENS YACHT CLUB.

Commodore, A. A. DAL MOLIN.
Vice-Commodore, B. C. CLARK, '95.
Rear Commodore, W. W. WARD, '95.
Secretary, S. A. HASBROUCK, '95.
Fleet Captain, F. F. OVERTON, '95.
Treasurer, F. R. CHAMBERS, '95.
Regatta Committee, B. C. CLARK, Chairman, G. L. TOWNSEND, H. S. STEVENSON, J. B. KREISCHER, and C. H. HUNT.
Membership Committee, C. T. CHURCH, Chairman, G. KOLLSTEDE, E. KEMBLE, H. BACKUS, and P. W. STRONG.
Entertainment Committee, P. A. HASBROUCK, Chairman, F. R. CHAMBERS, Jr., S. S. YARDLEY, A. CHURCH, and R. E. HALL.
Recruiting Committee, S. A. HASBROUCK, Chairman, W. W. WARD, B. C. CLARK, F. R. CHAMBERS, Jr., and G. H. HUNT.
Signal Corps Inspector, F. F. OVERTON.
Elected to Honorary Membership, G. OLIVER ISELIN.
Elected to Active Membership, S. H. STEPHENSON, '98.

THE FOLLOWING is the complete list of the Freshman Class, with post-office addresses:

ALLISON, P. L., 76 Hancock St., Brooklyn.
BAKER, F., 376 Hudson St., Hoboken, N. J.
BANG, A. C., 1214 Broadway, N. Y. City.
BARON, M. D., 107 E. 64th St., N. Y. City.
BATES, G. H., Crawford, N. J.
BLUMGARDT, J., 318 E. 86th St., N. Y. City.
BRETT, H., Matteawan, N. Y.

BUCKLEY, T. H., Tenafly, N. J.
CARPENTER, E. A., 171 W. 7th St., N. Y. City.
CHURCH, W. D., 17 Craig Pl., Plainfield, N. J.
CLARK, J. W., 120 Mercer St., Jersey City.
DAVIS, H. R., 16 Fairview Ave., Danbury, Conn.
DELAMATER, O. R., 424 W. 20th St., N. Y. City.
DOUGHTY, G. A., 710 Putnam Ave., Brooklyn, N. Y.
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INSTITUTE PERSONALS.

It is our endeavor to notice under this heading such items of news affecting graduates of the Institute as may interest their classmates and friends among the Alumni. We are indebted to a few members for regular or frequent contributions of items, and wish to make it known that the co-operation of all is most desirable, and will be appreciated. MANAGING EDITOR.

'75.

ADOLPH SORGE is Superintendent of the Twelfth Street Works of Fraser & Chalmers (Incorporated), Chicago, Ill.

'76.

GUS C. HENNING is the author of a paper published in *Cassier's Magazine* for October, entitled "How Materials Are Tested," in which he states and describes the various kinds of tests to some or all of which materials of construction are subjected in order to determine their quality.

'78.

A. W. GIBBS is Assistant Mechanical Engineer of Pennsylvania Railroad, and stationed at Altoona, Pa.

EDWARD P. THOMPSON announces that Prof. William A. Anthony, formerly of Cornell University, and more recently Consulting Electrical Engineer of the Mather Electric Co., is now associated with him, and will take charge of the engineering and expert work of the firm, while he will, as heretofore, superintend the procuring of patents.

'81.

ERNEST S. CRONISE, having severed his connection with Henry R. Worthington, has opened an office at 17 Broad Street, New York, where he will do a commission business in iron, steel, machinery, railway equipment and supplies, giving particular attention to export trade.

ALEX. C. HUMPHREYS, with his family, will reside for the winter at 12 Cumberland Terrace, Regents' Park, London, N. W.

Humphreys & Glascow have established their New York office in the Manhattan Life Building, Broadway, and their European headquarters at Westminster Chambers, 9 Victoria Street, London.

'83.

L. STROTHER RANDOLPH is Professor of Mechanical Engineering in the University of Virginia.

'84.

H. DE B. PARSONS is Professor of Steam Engineering at Troy Polytechnic Institute, where he delivers lectures twice a week from January to June.

ALEXANDER J. WURTS presented at the meeting of the American Institute of Electrical Engineers in Philadelphia, on May 15, 1894, an elaborate and excellently illustrated paper on "Discriminating Lightning Arresters and Recent Progress in Means for Protection Against Lightning."

'86.

O. F. PFORDTE presented a paper some time since before the American Institute of Mining Engineers on "The Cerro de Pasco Mining Industry," which, with additions by the author, was published in *Cassier's Magazine* for October, 1894, under the title of "Silver Mining in South America." Extracts from this paper, which is illustrated by numerous views of mining camps and localities at Cerro de Pasco, appear elsewhere in this issue.

EDWARD D. SELF received the degree of Engineer of Mines at Columbia School of Mines last June.

'87.

WALTER S. DIX is with the Metropolitan Traction Company in New York.

W. E. SCHOENBORN has been transferred from the Division of Metallurgy, and, for the past year, has been in the Division of Steam Engineering in the United States Patent Office.

'88.

ALTEN S. MILLER is located with the East River Gas Company, Long Island City, N. Y.

'89.

HENRY L. EBSEN has an article in *Cassier's Magazine* for August and for September on the "Auxiliary Machinery of an Ocean Greyhound," which serves to reveal to the reader, both by text and numerous

illustrations, what is known as the auxiliary plant of one of these great steamers.

FREDERICK GUBLEMAN has received the appointment of Assistant Supervising Engineer of the New Water-Works, Allegheny, Pa. His address is 34 Ohio Street, Allegheny, Pa.

W. W. JACKSON and Miss Ellen Winstanley Halton, of Providence, R. I., were married on October 31 at the residence of the bride.

ROBERT C. OLIPHANT is with the Harvey Electric Company, Newark, New Jersey.

HENRY J. PRENTISS is studying at the College of Physicians and Surgeons of the City of New York, with the Class of '95.

E. M. ROSENBERG is employed as draughtsman by the Metropolitan Traction Company, New York.

IRA F. WORTENDYKE has been appointed Superintendent of New Gas Light Co., Janesville, Wis.

'90.

R. S. TWITCHELL has been appointed to the chair of Physics and Chemistry at The Hill School, a well-endowed and influential school at Pottstown, Pa.

J. F. WESTCOTT and wife sailed for England on October 10. His address remains 269 Front Street, East, Toronto, Canada.

'91.

A. P. BOLLER, Jr., is connected with Henry R. Worthington Testing Department and may be addressed care of Hydraulic Works, Brooklyn, N. Y., though probably located for some months to come in St. Louis, Mo.

L. GRISWOLD KNOX has resigned his position with the Camden Iron Works to accept that of Instructor in Mechanical Engineering at Lehigh University, Bethlehem, Pa.

JULIUS OELBERMAN resigned his position with William Wharton, Jr. & Co., as Supervising Engineer, last June, and may be addressed at 115 North Sixteenth Street, Philadelphia, Pa.

ARDEN POST is draughting for the Metropolitan Traction Company, New York.

'92.

F. H. MCGAHIE is connected with the Maxim Powder and Torpedo Company, whose factory is at Lower Squankum, New Jersey.

'93.

HERBERT B. COOK is located with the B. F. Sturtevant Co., 135 North Third Street, Philadelphia, Pa.

HAROLD E. GRISWOLD is employed as Inspector by Middle States Inspection Bureau, 58 William Street, New York City.

CHARLES H. MERRITT, Jr., was married to Miss Clara Louise Meeker on Tuesday, October 24, at Danbury, Conn.

MORS O. SLOCUM has been transferred from the New York house to the Chicago works of the Western Electric Company.

'94.

THE East River Gas Co., of Long Island City, N. Y., has employed a number of Stevens graduates.

D. CORBIN, JOSEPH COTTIER, OLIVER ELLSWORTH, C. C. HARTPENCE, and ALFRED KOLLSTEDE are among our alumni who have secured positions with this company.

F. J. ANGELL is located at the Pennsylvania Railroad shops at Altoona, Pa.

H. D. COLEMAN, Jr., is with H. Dudley Coleman & Co., manufacturers of plantation machinery, New Orleans, La.

GEORGE W. COLLES is employed in the Pennsylvania Railroad shops at Hoboken, N. J.

J. M. COX has been appointed Assistant Superintendent of the Reading Terminal Station, Philadelphia, Pa.

W. B. O. FIELD is studying architecture at the "Ecole des Beaux Arts," Paris.

H. L. FRIDENBURG is studying for the degree of Electrical Engineer at Columbia College.

E. B. GALLAHER has opened an office as Consulting Engineer in the Postal Telegraph Building, New York.

WILLIAM GIBSON is located with the Snow Steam Pump Co. at Buffalo, N. Y.

J. W. GILMORE is Assistant Signal Engineer for the Hall Signal Company at 80 Broadway, New York.

W. A. JONES is draughting for Bement, Miles & Co., manufacturers of machine tools, Philadelphia, Pa.

C. C. KENYON is with the firm of Kenyon Bros., manufacturers of woolen machinery, at Raritan, N. J.

JOHN B. KLUMPP has entered the service of the United Gas Improvement Co., Drexel Building, Philadelphia, Pa.

F. M. OPPERMAN has been appointed Assistant Superintendent at the Works of the "Societé Anonyme des Glacies" at Courcelles, Belgium.

G. ROSENBUSCH is in the employ of the Sprague Electrical Elevator Co., Postal Telegraph Building, New York.

L. RUPRECHT is located with the Westinghouse Electric and Manufacturing Co., Pittsburgh, Pa.

R. W. SMITH is applying himself to sanitary engineering at Orange, N. J.

R. E. TAYLOR has been appointed Assistant Superintendent of Motive Power, N. Y. & N. E. R. R. His address is Norwood Central, Mass.

INDEX—Volume XI.

Accessions to the Institute Library.....62, 269
A Chemical Curiosity, Calcium Carbide..... 321
Aldrich, W. S., Some Observations on Shop Training..... 16
Alumni Association, Midwinter Meeting..... 144
Alumni Association, Annual Meeting..... 225
An Apparatus for Exploring Magnetic Fields as to Direction and Intensity..... 295
A Simple Water Prony Brake..... 105
Athletics.....52, 148, 238, 338
Automatic Fire Sprinkler Heads, Tests of..... 159

Braine, B. G., Test of Otto Gas Engine..... 185

Calcium Carbide, A Chemical Curiosity..... 321
Calorific Power of Coals, Determination of..... 110
Carbon in Iron and Steel, Determination of..... 306
Cold Storage, Comparison of Insulating Materials for..... 177
Commencement Week..... 208
Comparison of Insulating Materials for Cold Storage..... 177
Curious Custom-House Rulings..... 23

Dale, O. G., Determination of the Calorific Power of Coals..... 110

Engineering Fallacies..... 273
Errors of Measurements of Power by Steam Engine Indicators..... 65
Experimental Determination of the Quickness of Action of a Shaft Governor, and Theoretical Consideration of the Influence of an Inertia Weight..... 323
Extracts from the Engineering Press:
- **The Prospects for Our Shipyards.**
- **Large Steam Pipes.**
- **A Large Riehle Testing Machine.**
- **Weldless Chains.**
- **Standard Time in Italy** 50

Extracts from the Engineering Press (Continued):
The Commercial Element in Technical Education. L. S. Randolph, 83.
Wasteful Use of Exhaust Steam. A. Spies, '81.
Legal Protection of Mental Products. E. P. Thompson, '78.
A Large Locomotive of New Design.
Centrifugal Strains on Flywheels.
Large Steam Pipes.
Casting Steel Under Pressure.
Hard-Faced Steel Castings.
Hungarian "Railway Marks."
M. Pouchain's Electrically Propelled Carriage 131
Henry Morton. Coleman Sellers, E. D.
The Ferryboat of To-Day. E. A. Stevens.
Comparison of Formulas for Dimensions of Parts of Steam Engines. William Kent, '76.
The Ideal Preparatory School for Engineering Students. William Kent, '76..... 232
Silver Mining in South America. O. F. Pfordte, '86.
An Experiment with Lightning Arresters. A. J. Wurts, '84.
Auxiliary Machinery of an Ocean Greyhound. H. L. Ebsen, '80.
How Materials are Tested. G. C. Henning, '76.. 332

Gas Engines, Test of Otto... 185
Geyer, W. E., An Apparatus for Exploring Magnetic Fields as to Direction and Intensity.... 295
Griswold, H. E., Test of the New York Hygeia Ice-Making Plant.... 1

Heat, Transmission of Heat from Steam to Water Through Coils of Iron Pipe..... 24
Humphreys, Alexander C., Biographical Sketch..... 198
Hupfel, A. G., Test of the New York Hygeia Ice-Making Plant 1

Ice-Making Plant, Test of the New York Hygeia..... 1
Indicator, Errors of Measurements of Power by the Steam Engine.... 65
Inertia Weight, Influence on a Shaft Governor..... 323
Inglis, B. A., Determination of Heating Power of Coals.. 110
Institute Notes..... 55, 150, 242, 341
Institute Personals... ... 59, 154, 244, 345
Insulating Materials for Cold Storage, Comparison of..... 177

Jacobus, D. S., Errors of Measurements of Power by the Steam Engine Indicator..... 65
Tests of Automatic Fire Sprinkler Heads..... 159
Experimental Determination of the Quickness of Action of a Shaft Governor, and Theoretical Consideration of the Influence of an Inertia Weight..... 323

Kopp, G. C., Experimental Determination of the Transmisssion of Heat from Steam to Water Through Coils of Iron Pipe..... 24

LEAVITT, F. M., A Simple Water Prony Brake... 105
Lecture Notes on Engineering Practice:
Personal Conduct.
Value of Practice in Mathematics and in Use of Exact Expressions.
Broadening of the Field of Study is Widening of the Path of Life.
The Value of Experimental Work.
Ball Bearings.
Artificial Molding Sand.
Classification of Steel.... 86

MACDONALD, J. V., Test of Otto Gas Engines... 185
Mackenzie, W. P., Test of New York Hygeia Ice-Making Plant 1
Magnetic Fields, An Apparatus for Exploring..... 295
Mahler Calorimeter, Determination of the Calorific Power of Coals by Means of a..... 110
Merritt, C. H., Jr., Test of Otto Gas Engines.... 185
Meystre, F. J., Transmission of Heat from Steam to Water Through Coils of Iron Pipe..... 24
Morton, Henry, Curious Custom-House Rulings..... . 23
Theory and Practice in Technical Education. 130
Engineering Fallacies..... 273
Calcium Carbide, A Chemical Curiosity.... 321
The Manisman Process for Rolling Steel Tubes... 331

OBITUARY, Edward B. Wall..... 137
Oils Containing "Blown" Rape-Seed and "Blown" Cotton-Seed Oils, Analysis of Lubricating..... 45

PARKER, F. L., Comparison of Insulating Materials for Cold Storage, 177
Paulsen, J. F., Determination of Calorific Power of Coals by Means of a Mahler Calorimeter..... 110
Pipe, Transmission of Heat from Steam to Water Through Coils of Iron..... 24
Prony Brake, A Simple Water..... 105
Pyrometer, The Pneumatic 121

REVIEW and Experimental Determination of the Transmission of Heat from Steam to Water Through Coils of Iron Pipe..... 24
Riege, R., Comparison of Insulating Materials for Cold Storage..... 177

SELLERS, COLEMAN, Lecture Notes on Engineering Practice..... 86
Shaft Governor, Experimental Determination of the Quickness of Action of a.... 323
Shop Training, Some Observations on..... 16
Stillman, T. B., The Analysis of Lubricating Oils Containing "Blown" Rape-Seed and "Blown" Cotton-Seed Oils..... 45
The Determination of Carbon in Iron and Steel..... 306
Subject Catalogue of Graduation Theses..... 247

TEST of the New York Hygeia Ice-Making Plant..... 1
Tests of Automatic Fire Sprinkler Heads..... 159
Test of Otto Gas Engines..... 185
The Analysis of Lubricating Oils Containing "Blown" Rape-Seed and "Blown" Cotton-Seed Oils..... 45
The Champions of the Inter-Collegiate Lacrosse Association..... 236
The Determination of Carbon in Iron and Steel..... 306
The Determination of the Calorific Power of Coals by Means of a Mahler Calorimeter..... 110
The Manisman Process for Rolling Steel Tubes..... 331
The Pneumatic Pyrometer..... 121
Theory and Practice in Technical Education..... 130
Theses, Subject Catalogue of Graduation..... 247
Transmission of Heat from Steam to Water Through Coils of Iron Pipe, 24

UEHLING, E. A., The Pneumatic Pyrometer..... 121

WALL, EDWARD B., Obituary..... 137
Wall, Edward B., Portrait, opposite..... 65
Wilbor, A. G., Determination of the Calorific Power of Coals by Means of a Mahler Calorimeter..... 110

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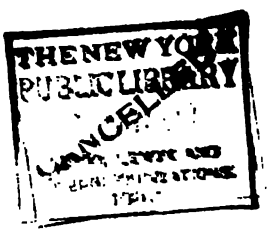
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VOL. XII. JANUARY, 1895. No. 1

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ASTOR, LENOX AND TILDEN FOUNDATIONS

MECHANICAL INTEGRATORS.*

BY PROF. J. BURKITT WEBB.

Various machines have been made or devised to perform arithmetical and many other mathematical operations, and such machines are increasing in reliability and adaptability to various uses with the improving facilities for their cheap and accurate manufacture.

Such machines fall into several classes distinguished by radical differences, one of the most evident of which is that between machines with a continuous and those with a discontinuous motion.

Machines with discontinuous motion are suited to problems in which the quantities to be operated upon are given in numerical form, which is practically discontinuous, becoming continuous only on the supposition that the decimal places are extended to infinity. In this class belong the great variety of *Calculating Machines*, the results as well as the given quantities being numerical and therefore discontinuous. Toothed wheels enter largely into the construction of machines of this class.

Machines with continuous motion are suited to problems given in geometrical form, which is essentially continuous. In this class belong a variety of Integrating Machines or *Mechanical Integrators*, or Integraphs, capable of performing with considerable accuracy more or less complicated operations of the Integral Calculus, or, in other words, of adding together mechanically an infinite number of infinitesimal elements into a

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finite result. These results are obtained in continuous form, though they are then usually made discontinuous to facilitate the numerical record thereof. The transmission of motion by friction wheels or surfaces is generally a characteristic feature of such machines.

The simplest Mechanical Integrator is one for measuring the lengths of lines by rolling a measuring-wheel of known circumference over them. It is especially useful on irregularly curved lines whose length cannot be found by the application of ordinary measuring rods or tapes. This instrument appears in a variety of forms, one of the oldest of which is the wheel used by blacksmiths for measuring the lengths of tires. The measurements, as seen upon the wheel, are in the continuous form, but if they are recorded, or read, from the wheel in numerical form they are thus made discontinuous. The Odometer, or road-measurer, is another common form of *Linear Integrator.*

A more complicated instrument is used for the measurement of areas, principally plane, though some of them can measure curved surfaces. Instruments for this purpose have been constructed in a variety of ways, more or less complicated, but the end can be obtained by means comparatively simple, as is done in Amsler's Planimeter, which will be discussed at some length, and which is the most important, reliable and useful instrument of its class.

Various other integrators of more complicated construction are used for evaluating more complicated integrals, and some of these are of practical importance. Thus, instruments are now in use for measuring the statical moment and moment of inertia of an area, which give good results and are not too complicated.

All such instruments, however, presuppose great accuracy with compartive cheapness of construction, and great care in their preservation and use. They are, in effect, mechanical extensions of the human brain, just as the immense number of tools employed in the arts are so many extensions of the hands.

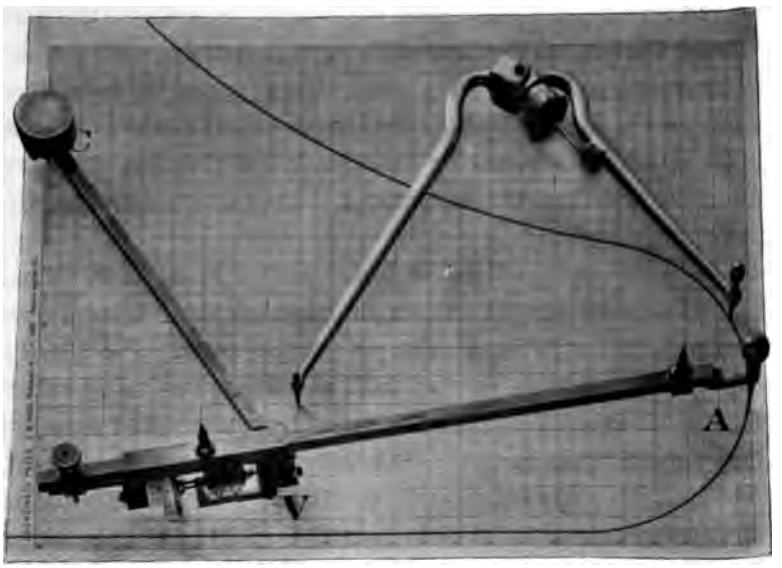


FIGURE 1. FIGURE 2.

AMSLER'S PLANIMETER.*

A number of instruments have been constructed for the measurement of plane areas, of which Dr. Amsler's is much the most in use and, perhaps, the most elegant in theory. It is remarkably simple in construction; in fact, it could not be more so, for, whereas a simple Linear Integrator must consist of two pieces at least--a frame of some sort and a measuring wheel this consists of but three. Apparently complicated in principle, the mathematical relations involved are elementary, and no better example can be given of the possibility of compassing complicated results by simple means.

* This article, including that portion on the POLAR TRACTRIX, was written ten years ago at the request of a friend, but in a form too condensed for publication. It has been considerably amplified, with no change, however, in its fundamental parts. -J. B. W.

DESCRIPTION OF THE INSTRUMENT.

In its simplest form this instrument consists of two bars VA and VC hinged together at V, Figs. 1, 2 and 6, with a wheel W mounted upon one of them. Other parts are sometimes added, as in Fig. 2, to allow the length of one of the bars to be changed at will, as will be explained; but this has no effect upon the action of the instrument, during which the length is not changed.

The Measuring-Wheel W has a periphery of some small and convenient length, as two, or two-and-a-half inches, quite narrow, and made hard so as to prevent wear. The wheel is graduated and has a vernier, with a counting device to record the number of revolutions, so that the distance traveled over by it may be accurately read off. It is mounted in journals as nearly frictionless as may be, and with as little lost motion as possible, so that the axis of the wheel may be held in its proper position. The wheel also furnishes one of three points for the support of the instrument when in operation.

The Measuring-Bar VA is provided at A with a dull-pointed *Stylus* and with suitable bearings for the Measuring-Wheel. The Stylus has such a length that, when the *Hinge* V is perpendicular to the plane of the paper and the Measuring-Wheel rests thereupon, it just touches it. The axis of the wheel should then be parallel to the paper and to a plane through the Hinge and Stylus. The lengths, VA of the bar, VB from the hinge to the plane of the periphery of the wheel, or *Wheel-Plane*, and BW of the wheel from B, which lies, of course, in the plane of the Hinge and Stylus, may be anything convenient.

The Radius-Bar VC is provided at C with a *Needle-Point*, whose axis is parallel to that of the Hinge, which serves, when it is thrust into the paper, as a pivot, about which the whole instrument revolves. The office of the Radius-Bar is, then, simply to guide the end V of the Measuring-Bar in the arc of a circle, while at the same time it assists in supporting the instrument

in its proper position over the paper. To aid it in doing this the Needle-Point has a shoulder, which rests upon the paper, and a weight is sometimes placed above it to keep it surely in contact. The position of the shoulder is such that when it and the other two points of support are resting upon the paper the Hinge is maintained in a position perpendicular to it. The length VC of the Radius-Bar is unimportant except as it affects the range over which the instrument will work, and several Radius-Bars of different lengths might be provided for the same instrument, or provision made for inserting lengthening-bars, to enable it to measure areas of widely different sizes.

METHOD OF USE.

To measure an area the Needle-Point is inserted at a suitable place in the paper, and the Stylus carried carefully over the boundary of the area, taking care to stop at the exact point from which the start was made, or, for greater accuracy, the boundary may be traversed a number of times continuously in one direction, and the result divided by that number. If the wheel was set at zero, the final *Reading* is taken, but if not, then from the final Reading must be subtracted that at which it started. This difference in the Readings gives the area, either directly, when the wheel is suitably graduated, or by a simple operation of multiplication and addition.

To those familiar with the instrument the foregoing may serve more as an analysis of the necessary parts and processes than as a description thereof.

NOTATION.

In the figures and references thereto positions or points and other objects are represented by Gothic type. Italics are used for numbers, distances, areas and other non-periodic quantities, and Greek letters stand for angles or arcs and other periodic values.

In a figure a character designating a value is placed, as a rule, near the middle point thereof, and arrow heads for indi-

cating the extent of the value are preferably dispensed with. Thus, in Fig. 6, p stands for the radius CW_1 of the Measuring-Circle, being at the middle point of no other distance. When a directed quantity is referred to by its terminal, or other, points they are mentioned in the order indicating its plus direction; thus VA is measured from V toward A.

Throughout the article, preferably;

A is the Stylus.

B is the point where the Wheel-Plane is pierced at right-angles by the line VA.

C is the Needle-Point.

B′ B and C indicate co-ordinate axes, however, in Fig. 15.

D, E, F, G, and H are used for bounding areas.

L is a supporting leg in Fig. 4 and a lens in Fig. 26.

M and N are intersections of a boundary line with the o-Circle. But in Fig. 23 M and N are points not on the circle.

O is an origin.

PQ is a right-line in Fig. 16.

U is the foot of a perpendicular from V on W_1C, Fig. 6.

V is the Hinge.

W, W_1 and W_2 are Measuring-Wheels, and

W′, W″, W‴, different positions of the wheel W.

X′X and Y′Y are co-ordinate axes.

Z is a point on the o-Circle.

Small letters and numerals are used to bound an area in Fig. 9 and elsewhere, and numerals also mark successive positions of a point.

A zero subscript is usually added to letters having a connection with the o-Circle, and the area, or equivalent area, of that circle is generally stippled in the figures.

A = the area of any curve.

A_0 = the area of the o-Circle.

R_1 and R_2 = the initial and final Readings of the Measuring-Wheel, expressed in revolutions of the wheel (or such frac-

tions of a revolution as may suit its special graduation).

R_1'' and R_2'' = the same in inches of the periphery.

$R = R_2 - R_1$ = the number of revolutions and parts thereof performed by the wheel while the Stylus is passing over a boundary or portion thereof.

$R'' = R_2'' - R_1''$ = the same in peripheral inches.

a = VA, the length of the Measuring-Bar.

b = VB, the distance from V to the Wheel-Plane.

c = VC, the length of the Radius-Bar.

m and n are axial intercepts in Fig. 16.

n = the number of turns about C made by the Stylus in measuring an area.

p = W_1C, the radius of the Measuring-Circle.

q = WC, the distance from the centre of the wheel to C.

r = AC, the distance from the Stylus to C.

r_0 = A_0C, the radius of the o-Circle.

w = the perimeter of the Measuring-Wheel.

x = the abscissa, and

y = the ordinate of a point.

α = the angle which the path of the wheel makes with its plane.

β = the angle which the Radius-Bar makes with the Measuring-Bar.

γ = the angle which the Radius-Bar makes with OX.

θ = the angle which the radius AC = r of the Stylus makes with OX.

These angles are supposed plus in the direction of motion of watch-hands, and the circuits of boundaries are supposed to be made in this plus direction.

Instead of the usual abbreviations of the names of common trigonometrical functions, the following symbols are used:

Λ for *sine*. and V for its reciprocal, the *cosecant*.

γ for *cosine* and $\angle$ for its reciprocal, the *secant*.

$\lrcorner$ for *tangent* and Γ for its reciprocal, the *cotangent*.

THEORY OF THE MEASURING-WHEEL.

In a simple Linear Integrator, when the wheel is moved over any curved line to find its length, it is necessary to steer it so that the Wheel-Plane is at every point tangent to the curve. For this purpose it matters little how the Wheel-Axis may be supported so that it has little friction and an accurately known length of periphery. It may be nicely fitted in its bearings, so that the plane of the wheel has a fixed position with respect to the handle of the instrument, or it may have considerable play endwise, so that this position changes constantly, without affecting the accuracy of its results.

In more complicated instruments, however, the wheel needs to be more carefully mounted, and should, in general, have no lost motion in its bearings.

The Wheel-Plane does not, moreover, remain tangent to the path over which the wheel is moved, in which case the latter is forced to slide over the paper in the direction of its axis, so that its motion consists of two components, the one a rolling perpendicular to, and the other a sliding in the direction of its axis. The relation between the motion of the centre of the wheel and its revolution must therefore be considered.

First. If a wheel be moved from W to W′, in the direction of its axis, see Fig. 3, it will slide over the paper and not revolve.

Second. If a wheel be moved from W to W″, in a direction perpendicular to its axis, it will revolve and not slide, and the distance measured off on its periphery will be W W″, the distance moved.

Third. If the wheel be moved in any diagonal direction from W to W‴, while the direction of its axis is not changed, its motion will consist of a sliding equal to W W′, and a rolling equal to W W″, so that it will still measure off on its periphery that component of its path which is perpendicular to its axis. This leads to the equation :

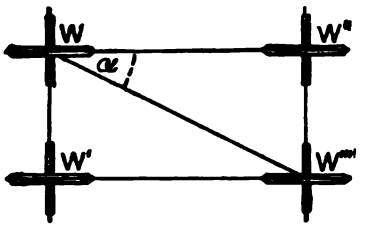


FIGURE 3.

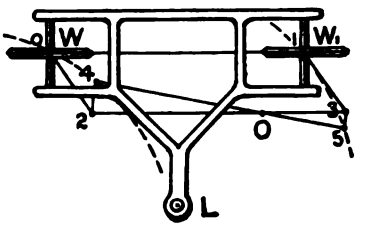


FIGURE 4.

Distance measured = *Path* × *cosine* α.

Fourth. Instead of the diagonal path W W''', the wheel may be moved over any path, straight or curved, from W to any point in the line W'' W''', the direction of its axis remaining unchanged, and the wheel will still measure the distance W W''.

Finally. If while the wheel is moved the direction of its axis is also changed, so that α, the angle between the Wheel-Plane and the path, is variable, the distance measured is found by integration, thus:

Distance = $\int$ *cosine* α × *differential of the path.*

There is not, however, any present occasion to use this formula, as the preceding one suffices to explain the action of the planimeter.

THEORY OF THE MEASURING-BAR.

First. The position of the wheel in the Wheel-Plane has no effect upon the distance measured, so that whether the wheel is placed at one side of the line VA, as indicated in the diagram, Fig. 6, or in the line (produced backward in the larger instrument), as shown in Figs. 1 and 2, is a question of convenience, of stability of the instrument and of the wear of the parts.

Fig. 4 represents two wheels, W and W_1, mounted in the same plane in a frame, which has a foot at L simply to keep it from upsetting. Let this frame receive any motion whatever; then the distances measured off by the two wheels will be the same. For any motion may be resolved into an infinite

number of differential motions for which the statement is evidently true, or may easily be shown to be, consequently it is true for the whole motion. Let one of the differential motions carry the wheels from the position 0 1 to a neighboring position, as 4 5 Through any point O in the line 4 5 draw 2 3 parallel to 0 1, with O 2 = O 4 and O 3 = O 5. Connect 0 with 2, and 1 with 3; then will the differential motion be resolved into a translation of the frame, which carries the wheels over the equal and parallel paths 0 2 and 1 3, and a rotation of the same about the point O, which moves the wheels, in the directions of their axes only, from 2 to 4 and from 3 to 5, respectively. Evidently this last motion will not cause the wheels to revolve and, as the translation is the same for both wheels, it must cause the same revolution in both, therefore the effect of the whole differential motion is to cause the same revolution in both wheels, Q. E. D.

It follows from the above that the revolution of the wheel W in Fig. 6 must be the same as if it were at B, or at any other point, as W_1, in the Wheel-Plane.

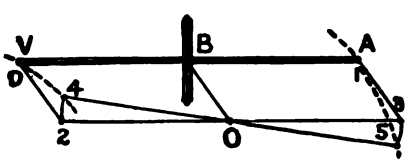


FIGURE 5.

The simplest form of Measuring-Bar is that shown in Fig. 5, having a wheel at its centre B. The bar itself may even be nothing more than the wheel-axle extended to V and A. Evidently such a bar in passing from one position, 0 1, to the next, 4 5, records the area of the quadrilateral, 0 1 5 4, swept over by the bar; for this area is equal to that of the parallelogram 0 1 3 2, inasmuch as the positive triangle O35 equals the negative triangle O24, the triangles 0 2 4 and 1 3 5 being neglectable for positions a differential distance apart, and the area of the parallelogram is equal to the distance measured by the wheel, that is, the perpendicular distance between 0 1 and 2 3, multiplied by the length *a* of the bar VA, or, if the Measuring-Wheel is suitably graduated, by simply subtracting the Reading at B from that at O.

It follows from this that if the two ends of such a Measuring-Bar be made to move over two curves, as indicated in the figure, the wheel will show the area contained between the latter and the initial and final positions of the bar.

In the ordinary planimeter, however, the wheel is not in the centre of the bar, and its action therefore will be treated of in a more general way after having discussed the particular system of co-ordinates embodied in the instrument.

THEORY OF THE RADIUS-BAR.

The Radius-Bar may be said to have no special theory. It may even be dispensed with and the Hinge of the Measuring-Bar made to follow the arc of a circle in some other way. It is moreover simpler, as will soon be seen, to consider the Measuring-Bar and Radius-Bar together.

CO-ORDINATE SYSTEM OF THE INSTRUMENT.

The instrument is represented in Fig. 6 as engaged in measuring the area MAND. Put the Stylus at any point A_0, so that the plane of the wheel passes through C. B_0C is the Wheel-Plane in this position and V_0 the Hinge. Describe the circle Y'OY with the radius CA_0 and centre C; this is called the *Zero-Circle*, because if the Stylus be made to follow it the motion of the wheel will be wholly in the direction of its axis and the *wheel will not revolve*.

A radius CX and the Zero-Circle Y'OY are the two axes of a system of *rectangular co-ordinates* whose origin is at O, and the instrument measures areas by means of this system.

COMPARISON WITH THE COMMON RECTANGULAR SYSTEMS.

The common system of rectangular co-ordinates, though the simplest in itself and for many problems, is not so for all. Its peculiar simplicity is that it is at the same time rectilinear; now the planimeter system is rectangular and semi-rectilinear. The common system supposes the plane to be divided into infinitesimal rectangular elements by two systems of parallel right-lines at right-angles with each other, while the planimeter

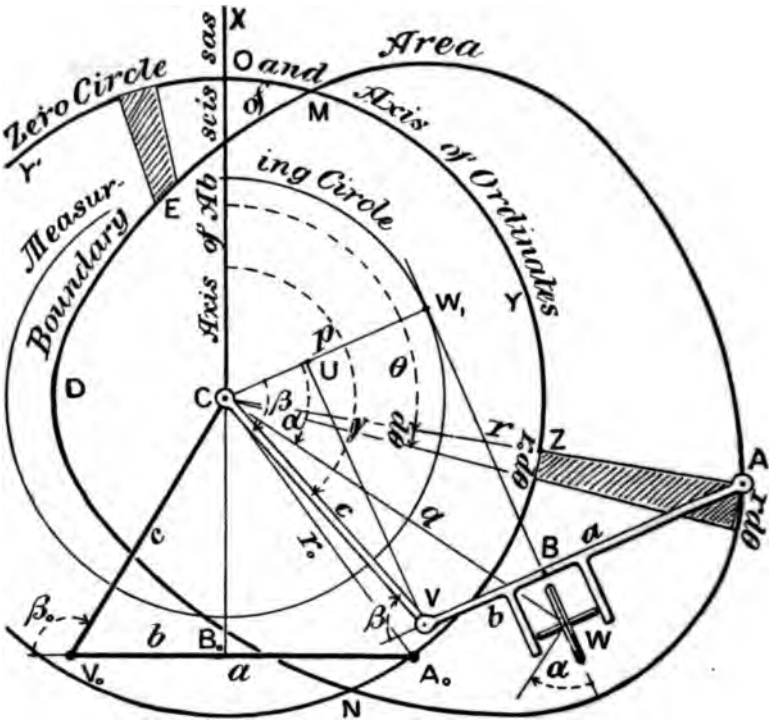


FIGURE 6.

system divides the plane into rectangles by a system of concentric circles, crossed at right-angles by a system of radii. In the common system the elements may be all squares of the same size, while here, though they can all be squares, the sides of the squares must be proportional to their distances from C.

The correspondences existing between the two systems are shown by the following statements:

In both systems there is a rectilinear axis of abscissas OX.

The axis of ordinates Y'OY is rectilinear in the common system and circular in that of the planimeter. In both systems there are elementary infinitesimal strips made by drawing right-lines perpendicular to Y'OY through equi-distant points thereof.

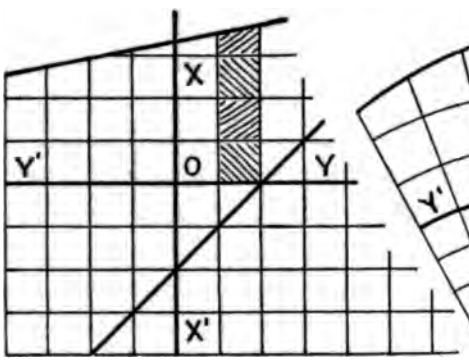


FIGURE 7.

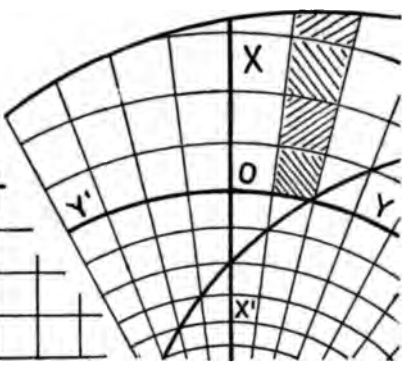


FIGURE 8.

There may also be square elements in both, formed by cutting up the infinitesimal strips by lines parallel to Y'OY, at distances apart equal to the width of the strips at that place.

Figures 7 and 8 illustrate the above points, and show also that the diagonals of successive elements form a right-line in Fig. 7, while in Fig. 8 they form a logarithmic spiral.

The common system of polar co-ordinates is different from Fig. 8, not being so simple, consistent or elegant. In it the ordinates, called angles or arcs, are measured from O along OY, but this circle is restricted to unity radius. The abscissas, called radii, are not however measured from the origin O, but from C.

MEASUREMENT OF THE AREA.

Figure 9 shows an area composed of a number of strips abutting upon a portion of the Zero-Circle, OY, which is here for convenience made a right-line; it does, in fact, become a right-line in a particular form of planimeter called Coffin's Averaging Instrument. Fig. 9 is not necessarily a part of Fig. 6, and the proof applies to it when the strips are supposed to have finite dimensions.

Figure 10 is an enlarged view of the end of one of the strips in Fig. 9 on the supposition that those strips are infinitesimal; it therefore represents equally the end of a strip in Fig. 9, sup-

posed to be cut off obliquely, and also the end of one of the elementary areas in Fig. 6, which actually have oblique ends.

The area MAND, Fig. 6, equals the algebraic sum of all its elementary infinitesimal strips, such as are shown at ZA and E whose algebraic signs are determined by a rule to be given. It makes no difference, so far as the area is concerned, whether these strips are supposed to have ends cut parallel to the Zero-Circle, as indicated at A, or to be oblique, as shown at E, because the area of the small triangle thus disregarded at A is a second differential only, and the integration of such triangles around the whole boundary could not give more than a first differential of area. But, as the Stylus actually follows a diagonal line across the ends of these elementary strips, it will be better to consider them as having oblique ends and to show how this affects the action of the Measuring-Wheel.

In Fig. 9, also, the area is the sum of its elements. Consider now the action of the wheel when the Stylus is passed around the boundary of one of the elements, as around 3gh43. Evidently if the area of this strip is measured by the wheel it must be measured as the Stylus passes over its end gh, for the reason that on 4 3, a portion of the Zero-Circle, the wheel does not revolve, and whatever revolution occurs in passing from 3 to g must be exactly neutralized by a contrary revolution in passing back over the equal distance from h to 4.

FIGURE 10.

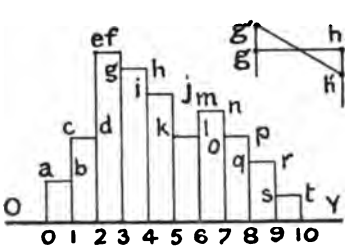


FIGURE 9.

It follows, therefore, that if the Stylus be passed around the whole area, Fig. 9, composed of these elementary strips, or even from o through a, over the upper part of its boundary only, to 10, the wheel will measure the whole area o f 10 if each elementary area is measured as the Stylus passes over it, because

evidently the total turning in one direction of the wheel for such parts as bc, lm, must be neutralized by the turning in the contrary direction for such parts as rs, whose direction is opposite, the algebraic sum of all such parts from o to 10 being necessarily 0. For the oblique-ended strips of Fig. 6 we shall however, need a somewhat different proof to show that the same is true.

LEMMA.—*The passage of the Stylus over the boundary of a strip of infinitesimal width causes the wheel to record its area whether its end is oblique or rectangular.*

Proof.—Fig. 10 shows the end gh of one of the strips in Fig. 9. On the supposition, however, that the Stylus passes in a curved line over the boundary, let g'h' be the end of the strip. Now when the Stylus passes from g' to h' the wheel will pass from some point G to H, not shown. Through G and H suppose lines drawn parallel to the wheel-axis at those points. These lines will be parallel because the wheel-axis cannot change its direction a finite amount in passing over the distance G H, which is infinitesimal because g'h' is; but they will not necessarily be parallel to any line in Fig. 9. Now it has been shown in connection with Fig. 3 that the wheel must register the same amount, in passing from one parallel line to another without changing its direction, whether it passes by one path or another, consequently, by passing the Stylus over the path gg'h'h the same record is made as by passing it over the rectangular end gh.

Suppose, now, that the Stylus starts at h with the wheel reading R_1 and goes through h' (R_1' being the corresponding Reading), 4 and 3 to g, it must arrive at this point with the same reading R_1 as it had at starting. From g the boundary of the square-ended strip may be completed by passing directly to h, arriving there with a Reading R_2, or an increase

$$R = R_2 - R_1$$

of the Reading due to a circuit of the square-ended area.

On the other hand, the Stylus may go from g first to g′ and then through h′ to h, at which point the Reading will still be R_2, because, as already shown, the wheel registers the same amount over the two paths from g to h. But the Stylus has now made the circuit of the oblique-ended strip, besides going over hh′ twice, in contrary directions, which makes no difference in the area of the strip nor in the Reading, consequently the circuit of the oblique-ended area gives the same result

$$R = R_2 - R_1$$

as the circuit of the square-ended area.

The same result is obtained by subtracting the two Readings for the point h′, thus :

$$R = R_2' - R_1'$$

where R_2' is the Reading after arriving at h′ from g′, for evidently R_2' equals the Reading at g plus the increase for the path ghh′ from g to h′, or

$$R_2' = R_1 + (R_2 - R_1) + (R_1' - R_1) = R_2 - R_1 + R_1'$$

therefore

$$R = R_2' - R_1' = R_2 - R_1 \qquad \text{Q.E.D.}$$

Corollary.—We see then, also, that the partial circuit of an element, beginning and ending at the Zero-Circle, and consequently omitting part of the boundary on the circle, or even beginning and ending at equal distances from the circle, gives the same result for an oblique as for a square-ended element, so that the effect of the change in β upon the revolution of the wheel while the Stylus passes over the oblique end of the strip, is cancelled out by returning β to its initial value.

PROPOSITION I.—*The passage of the Stylus around any elementary strip causes a revolution of the wheel proportional to the area of the strip, and the distance measured off by the wheel, multiplied by the length of the Measuring-Bar, gives the area of the strip.*

For the simplification of the proof only we adhere to elementary areas whose sides are perpendicular to the Zero-Circle, and shall, also, in accordance with the Lemma, suppose their

ends to be rectangular. This makes the proposition equivalent to the statement that when the whole instrument is revolved about C, so that θ increases while β remains constant, the wheel registers an amount R proportional to the area swept over by the abscissa ZA_0, Fig. 6.

Proof.—In the oblique triangle AVC, Fig. 6, we have for any point A

$$r^2 = a^2 + c^2 + 2ac \cos\beta$$

which becomes

$$r_0^2 = a^2 + c^2 + 2ac \cos\beta_0$$

when β has such a value, β_0, as causes the Wheel-Plane WB to pass through C. This is shown in the black position of the instrument, which determines the radius r_0 of the Zero-Circle and in which position it may be revolved as a whole around C without revolving the wheel.

Also, the area dA of the elementary strip ZA is

$$dA = \tfrac{1}{2}(r\,d\theta + r_0\,d\theta)\cdot(r - r_0)$$
$$= \tfrac{1}{2}(r^2 - r_0^2)\,d\theta$$

which becomes by substituting the above values of r^2 and r_0^2

$$dA = ac\,(\cos\beta - \cos\beta_0)\,d\theta.$$

Now, as shown in connection with Fig. 4, the revolution of the wheel at W is the same as if it were at W_1, the foot of a perpendicular from C upon the Wheel-Plane, so that while the Stylus passes over the distance $r\,d\theta$ at the end of the element, with β constant, the wheel measures off the distance $p\,d\theta$. But

$$p = CU + UW_1 = CU + VB$$
$$= CU + V_0B_0$$

where, from the triangle CUV, we have

$$CU = c\cos\theta$$

and, from the triangle CB_0V_0,

$$V_0B_0 = b = -c\cos\beta_0$$

so that $$p = c\,(\cos\beta - \cos\beta_0)$$

and the distance measured off by the wheel is

$$p\,d\theta = c\,(\cos\beta - \cos\beta_0)\,d\theta$$

which, when multiplied by a, is the value already obtained for dA. We may therefore write

$$dA = apd\theta \qquad \text{Q. E. D.}$$

The rotation of the wheel may also be calculated for the wheel at W, as follows :

While the Stylus moves over $rd\theta$, without change of β, the wheel moves over the distance $qd\theta$ in a direction whose angle with the Wheel-Plane is α, consequently by the formula produced under Fig. 3 the wheel measures off the distance

$$q \curlywedge \alpha \, d\theta \quad .$$

But $$q \curlywedge \alpha = p$$

therefore the distance measured off is, as before, $pd\theta$.

PROPOSITION II.—*The passage of the Stylus along any curve, commencing and finishing with the same value of β, causes a revolution of the wheel proportional to the area between the curve and the Zero-Circle, and the distance measured off by the wheel multiplied by the length of the Measuring-Bar, gives the area thus swept over by the abscissa of the curve.*

Thus in Fig. 11 the passage of the Stylus over FGH causes a revolution proportional to the area $F_0 FGHH_0$, but if the area $F_0 FGG_0$ is to be measured, the Stylus, after going over FG, must be passed from G to G_1 to bring β back to its initial value, F_1, G_1 and H being at the same distance from the o-Circle.

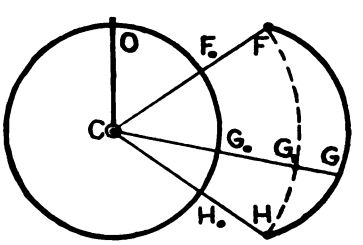


FIGURE 11.

Proof.—From the corollary under the lemma the partial circuit of an element, made by going along one side, as from Z to A, Fig. 6, across the end, either rectangular or oblique, and back along the other side to the o-Circle, causes a revolution of the wheel proportional to the area of the strip, consequently by starting at F_0 and making such partial circuits of the elements in order, we may, by a continuous motion of the Stylus,

proceed from F_0 to G_0 or H_0, thus causing a total revolution of the wheel proportional to the whole area F_0FGG_0 or F_0FHH_0 But all the abscissas, or partial radii, separating the elements are thus passed over by the Stylus twice, in contrary directions, also the motion over HH_0 or GG_0 is equal and contrary to that over F_0F, consequently the total revolution of the wheel due to the radial motions of the Stylus is nothing, and we may omit these motions altogether and pass the Stylus continuously along the curve from F to H or G without changing the final Reading of the wheel, so that, the initial and final Readings in peripheral inches being R_1'' and R_2'' and A being the area, we must have

$$A = a R'' = a (R_2'' - R.'') \qquad \text{Q. E. D.}$$

Here a is supposed to be in inches, and the wheel being graduated so that its Readings correspond with inches measured off by its periphery, A will be in square-inches; but if the unit of the Readings is any other distance, say u inches, then A will be given in rectangular units of u square-inches each. To avoid this complication and at the same time make a disappear from the formula the wheel is often graduated so that the Reading is a times the peripheral measure, which evidently changes the formula so that the number of square-inches area is

$$A = R = R_2 - R_1$$

To distinguish these Readings from each other the unaccented R is used for Readings of wheels graduated to dispense with the factor a, while the double accent indicates inches of periphery.

ALGEBRAIC SIGNS OF THE ELEMENTS.

As the sign of an area must depend primarily upon the signs of its differential elements, which depend upon

$$\gamma\beta - \gamma\beta_0$$

the sign of this quantity must be examined in the four following cases, which depend upon whether the Stylus is outside or inside of the o-Circle; whether the instrument as a whole revolves forward or backward, *i. e.*, whether θ increases or diminishes,

or, in other words, whether $d\theta$ is plus or minus; and whether the wheel revolves so as to increase or decrease the Reading.

Suppose the wheel to be graduated so that when the Stylus is outside the o-Circle and β plus, an increase of the Reading accompanies an increase of θ; then for

$$\beta > o \text{ and } < 180°$$

I. $(\nearrow\beta - \nearrow\beta_0)$ is plus; $d\theta$ is plus; $d\theta$ is plus.
II. $(\nearrow\beta - \nearrow\beta_0)$ is plus; $d\theta$ is minus; $d\theta$ is minus.
III. $(\nearrow\beta - \nearrow\beta_0)$ is minus; $d\theta$ is plus; $d\theta$ is minus.
IV. $(\nearrow\beta - \nearrow\beta_0)$ is minus; $d\theta$ is minus; $d\theta$ is plus.

It should be remembered that, on account of the change in β, a wheel graduated to increase its Reading with an increase of θ may sometimes act in the contrary way, but as it is necessary to finish the measurement of areas with β returned to its initial value, thus eliminating the effect of β's variability, the wheel may be regarded as always virtually revolving in the same way as θ when the Stylus is outside the o-Circle, and in the contrary direction when inside.

ALGEBRAIC INTEGRATION OF THE DIFFERENTIAL ELEMENTS.

Let us return now to the equation

$$dA = a\,p\,d\theta$$

where a is the Measuring-Bar and p the perpendicular from C upon the Wheel-Plane. Substituting the value of p we get

$$dA = a\,c\,(\nearrow\beta - \nearrow\beta_0)\,d\theta.$$

In this equation β and θ are both variable, and to integrate algebraically it must be known whether they are dependent or independent of each other. Inasmuch as the Stylus follows a curve they are dependent, but in what manner depends upon the shape of the curve, and therefore in the general discussion of the planimeter the right-hand member of the equation cannot be integrated algebraically. In fact, the value of the planimeter lies largely in the fact that it dispenses with all knowledge of the law (or absence of law) connecting θ and β and integrates mechanically.

But any integration is liable to introduce a constant, which in this case is the area of the o-Circle. In the simple case in which the area to be measured is a circle outside the o-Circle and concentric thereto, β is constant and the integration shows, what is otherwise quite evident for any closed curve outside of the o-Circle, that, after adding together all the infinitesimal strips between such a curve and the o-Circle, the area of the latter must be added to complete the area of the curve.

THE ZERO-CIRCLE.

The o-Circle has for its area

$$A_0 = \pi r_0^2 = \pi (a^2 + c^2 + 2ac \cos \beta_0)$$
$$= \pi (a + c)^2 - 2\pi ca (1 - \cos \beta_0)$$

But it has been found that

$$\cos \beta_0 = -\frac{b}{c}$$

and therefore

$$1 - \cos \beta_0 = \frac{b + c}{c}$$

which substituted gives for the *area of the* o-*Circle*

$$A_0 = \pi r_0^2 = \pi (a + c)^2 - 2\pi a (b + c).$$

The quantities a, b and c can be obtained from the instrument and this value calculated, or a circle may be described by the Stylus, with such a value of β as causes no revolution of the wheel and the diameter thereof measured.

The most accurate way of performing the latter operation is to set the Stylus at a fixed distance r_1 slightly less than r_0 from C, by means of a strip of cardboard. The Needle-Point is pressed through one end of this into the paper and the Stylus dented slightly into the other end and kept from moving with a bit of wax. With the wheel resting on the paper the whole is then revolved around C until, by a mark on the strip of cardboard and another on the paper, several exact revolutions are known to have been made. The wheel is read before and after and the difference taken and divided by the number of revolu-

tions. Call the result R_1. The Stylus is then moved outward to a distance r_2 from C slightly greater than than r_0 and the process repeated, the result being called R_2. The revolution of the wheel will now be in the contrary direction, and if the two Readings differ but little numerically the value of r_0 can be obtained with accuracy by the equation

$$r_0 = r_1 + (r_2 - r_1)\frac{R_1}{R_1 + R_2}$$

where both R_1 and R_2 should be obtained by subtracting the lesser Reading from the greater, so as to be plus quantities.

INSTRUMENTAL CONSTANTS.

To get the value of the *Instrumental Constants* a, b and c from the instrument in cases where there is sufficient motion to the joint V, we may proceed advantageously as follows:

Fasten a block upon the drawing-board so that one of the bars can be held firmly against it, the Needle-Point or Stylus, as the case may be, being also pressed into the paper to keep the bar in place; suppose also that the arm VC has thus been fixed in position. Now revolve the bar VA nearly to its extreme position and mark the position of the Stylus by pressing it slightly into the paper, at the same time adjusting the bar so that it appears parallel to a line previously drawn on the paper for this purpose. Then revolve the arm VA into its second parallel position, 180° from the first, removing the instrument temporarily from the board for greater convenience, if necessary. Again marking the position of the Stylus the half-distance between the two marks will be a. b can be found at the same time by causing the wheel also to leave its mark upon the paper, and to get c the arm VA must be fixed by the Stylus and block. When positions 180° apart cannot be used on account of the limited motion of the Hinge, three or more positions can be marked over as wide a range as possible and circles can be passed through them by geometrical principles or by trial, whose diameters can then be measured. Any looseness of the

Hinge should, of course, be removed before attempting to determine the Instrumental Constants. A looseness of the wheel, also, may interfere with the correct determination of the o-Circle, and of b, and result in a discrepancy between its radius as measured and as calculated from the constants.

MEASUREMENT OF A CLOSED AREA.

The final proposition can now be stated:

PROPOSITION III.—*The passage of the Stylus once around any closed curve, starting from any initial position and finishing at the same point, at which finish* β *must have* returned *to its initial value and* θ *have its initial value plus* n *times* 2π, *causes a revolution of the Measuring-Wheel proportional to the area* A *of the curve diminished by* n *times the area* A_0 *of the Zero-Circle; and the distance* R'', *measured off by the wheel, when multiplied by the length* a *of the Measuring-Bar and added to* n *times* A_0, *gives the area* A *of the Curve;*

or,
$$A = n A_0 + a R''$$

Proof. It will be sufficient here to prove this for $n = o$ and $n = 1$, which are the ordinary cases, leaving the explanation of other values of n to be made under the headings PLUS AND MINUS AREAS, FORMS OF AREAS, etc.

These two cases are usually distinguished from each other as cases having C without and within the area, respectively, and the β requirement is usually neglected on the supposition that it is unnecessary for a closed area. We shall, however, under the headings FORMS OF AREAS, CROSSED BOUNDARIES, POLAR TRACTRIX, etc., see the propriety of the proposition as stated above.

For $n = 1$ we have the case, already considered, in which the o-Circle lies wholly within the curve. But such areas as MAND, Fig. 6, belong equally to this case, because as long as the centre C is within the curve, the curve circumscribing this centre one or more times, the o-Circle itself is virtually within. This will be seen by considering that for the area MAND, Fig. 6

the element at E is minus, under Case III of the table of SIGNS OF THE ELEMENTS, and that therefore the area must equal the o-Circle plus the area between it and the curve, *i. e.*, plus that portion between the circle and MAN and plus the minus portion, also, between it and NDM. This will be explained further under FORMS OF AREA.

For the case, then, where $n = 1$, the Needle-Point C being within the curve, we have

$$A = A_0 + a\,(R_2'' - R_1'') = A_0 + aR''$$

or $$= A_0 + (R_2 - R_1) = A_0 + R$$

according to the graduation of the wheel.

For $n = o$ the Needle-Point lies outside the o-Circle and θ returns to its original value. While θ increases we get plus elementary areas, and by decreasing θ, minus ones, the area consisting simply of the algebraic sum of these areas, as may be readily seen, and as will be further shown under the head mentioned, so that when $n = o$ we have simply

$$A = a\,(R_2'' - R_1'') = a\,R''$$

or $$= R_2 - R_1 = R$$

according to the graduation.

INITIAL POSITION OF STYLUS

It is to be remarked that in making a circuit of any area it is important to stop the Stylus exactly at its starting point. Also that this initial or starting point is best chosen as near the o-Circle as possible, where the elementary areas are shortest, or upon it, where a slight inaccuracy in stopping can produce no error.

AREAS AS ANNULI.

We may regard the Measuring-Wheel of the planimeter, see Fig. 6, as driven by the Measuring-Circle CW_1 by means of a quarter-twist belt, running upon wheel and circle as upon two pulleys whose shafts are at right-angles with each other, and the Measuring-Circle may even be regarded as an expanding pulley to allow of changes of radius due to the change in β.

The line WW_1 is the centre line of the driving side of this belt, the other side being lacking. In fact, if the sliding of the paper past the wheel in the direction of the wheel-axis be neglected, the paper is such a belt, for it is equally proper in measuring an area to suppose that the paper is revolved beneath the instrument as to assume that the instrument revolves upon the paper. Therefore, as shown for particular cases in Figs. 12 and 13, the wheel simply measures the mean length of an annulus, or curved strip, whose width is a and whose area is the area of the curve less that of the o-Circle, or $A - A_0$. In Figs. 21 and 22 it will be seen also that, the area described by the Stylus being equal to zero, the wheel measures A_0, plus or minus according to the way the instrument revolves about C.

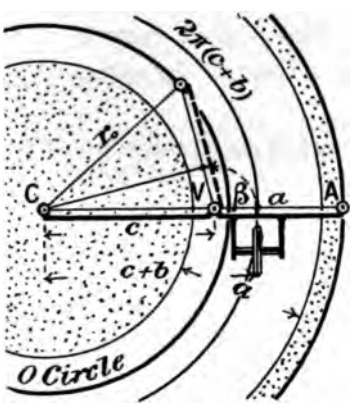


FIGURE 12.

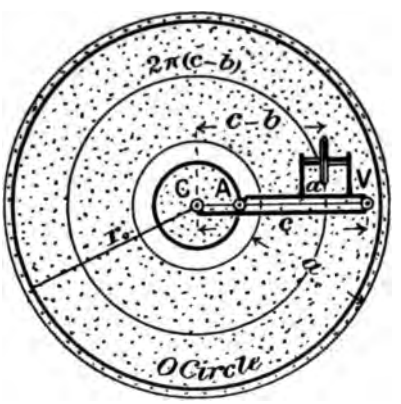


FIGURE 13.

The area of the o-Circle appears also as a circular area plus an annulus or as an annulus alone. Thus its value may be written either

$$A_0 = \pi r_0^2 = \pi (c + a)^2 - 2\pi (c + b) \cdot a$$

or $$A_0 = \pi r_0^2 = \pi (c - a)^2 + 2\pi (c - b) \cdot a$$

The first expression consists of the circular area described by A with the radius $c + a$, shown in Fig. 12, minus an annulus or curved strip whose mean length $2\pi (c + b)$ is measured by

the wheel, and whose width is a; thus A_0 consists of the two shaded areas that remain, a circle and an annulus. The planimeter is here represented as fully open, disregarding the fact that it may not be possible to open the actual instrument thus far.

In Fig. 13 the second value is illustrated, and A_0 is composed of the shaded circle, described by A with the radius $c - a$, plus the annulus , of length $2\pi(c - b)$ and width a, also shaded, which is measured by the wheel.

In both figures the o-Circle is drawn with the radius r_0 obtained from the equation.

$$r_0^2 = c^2 - b^2 + (a - b)^2$$

or

$$= c^2 + a^2 - 2ab;$$

both of these are simple geometrical values from the geometrical figure $C V_0 B_0 A_0$ of Fig. 6, which is here shown dotted. Thus the eye may easily judge of the correctness of the values of A_0 as shown.

In both figures, also, we may regard A_0 as made up of the circle described by the Stylus less the annulus of width a measured by the wheel, because in Fig. 13 the wheel will revolve in a contrary direction from Fig. 12, and thus make the annulus itself minus, so that the numerical sum will result.

When the Wheel-Plane bisects the Measuring-Bar, or

$$a = 2b$$

the outer annulus of Fig. 12 and the intervening one of Fig. 13 disappear and leave A_0 as a circle of radius

$$r_0 = c .$$

On the other hand, when the Wheel-Plane in Fig. 12 is placed within half a of the centre, *i. e.* when

$$b = -(c - \tfrac{1}{2} a)$$

or

$$a = 2(c + b)$$

the hole in the annulus measured by the wheel disappears, leaving the measured area a circle with A_0 as an annulus outside of it.

ZERO-CIRCLE AND CO-ORDINATE CONSTANT.

In further comparison of the planimeter and common systems of co-ordinates, it is easy to show the similarity between a constant of the rectangular system and the o-Circle.

Thus, to get the area of PYQ, Fig. 14, by integration, the line PQ should first be expressed by its equation

$$x = \frac{m}{n}(y - n)$$

Summing now the infinitesimal strips x long by dy wide,

$$A = \int x\,dy = \frac{m}{n}\int (y - n)\,dy$$

or

$$A = \frac{m}{n}\left(\frac{y^2}{2} - ny\right) + c.$$

Putting now $y = 2n$

$$A = -\frac{mn}{2} = \frac{m}{n}(2n^2 - 2n^2) + c$$

which requires

$$c = \frac{mn}{2};$$

so that the integration does not give the correct result without the addition of the shaded triangle, and *may* be regarded as adding together only those strips which lie above it.

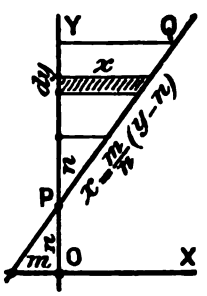


FIGURE 14.

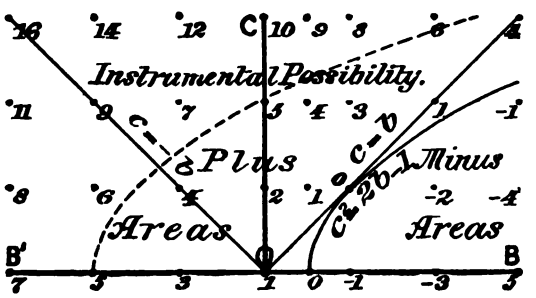


FIGURE 15.

ALGEBRAIC SIGN OF THE ZERO-CIRCLE.

The area A_0 may have either sign or be equal to zero according to the values of the Instrumental Constants a, b and c.

Not only may the area of the o-Circle, as already shown, appear in forms other than a circle, but in many cases it does not exist as a circle that can be described by the Stylus, there being no position of the instrument for which the Wheel-Plane passes through the Needle-Point.

The generality of what follows will not in the least be affected by restricting the length of the Measuring-Bar to unity. Putting an extra subscript to the area to indicate this the formula for the area of the o-Circle:

$$A_0 = \pi (c^2 + a^2 - 2ab)$$

becomes $$A_{01} = \pi (c^2 + 1 - 2b)$$

from which it appears that when

$$2b > c^2 + 1, \quad A_{01} \text{ is minus;}$$

when $$2b = c^2 + 1, \quad A_{01} = 0;$$

and when $$2b < c^2 + 1, \quad A_{01} \text{ is plus;}$$

which are the *Criteria for Algebraic Signs.*

The sign of c disappears in squaring so that c may always be regarded as plus.

Therefore to have a plus o-Circle b must lie between $-\infty$ and half of $c^2 + 1$

All plus o-Circles are not, however, *instrumentally possible*, *i. e.*, there may be no position of the instrument such that the Stylus can describe the circle with the Wheel-Plane passing through C.

The *Criterion for Instrumental Possibility* is:

$$b^2 < c^2$$

i. e., b must be numerically less than c.

Comparing this with the first Criterion for Signs it is seen that all minus o-Circles require b to be greater than half of $c^2 + 1$, and consequently greater than c, inasmuch as half of $c^2 + 1 = c$ for $c = 1$ and is greater than c for all other values. This might also be anticipated from the fact that the radius,

$$r_0 = \sqrt{A_0} \div \sqrt{\pi},$$

becomes imaginary when A_0 is minus.

The *graph* of the Criteria, Fig. 15, shows what plus circles are instrumentally possible. Thus for any point on the parabola $c^2 = 2b - 1$, and for this relation between b and c the o-Circle disappears. The region within the parabola is the region of minus circles, and without, that of plus circles. The region of Instrumental Possibility lies between the two lines $c = b$ and $c = -b$. The upper one of these lines touches the parabola at $c = b = 1$, for which point the circle has a differential radius and is instrumentally possible. The figures at the different points marked by dots, mostly at integral values of b and c, are the calculated values of r_0^2 for these values of the co-ordinates, and it will be seen that the locus of b and c for any particular value of A_0 is a parabola, as shown dotted for $r_0^2 = 5$, all such parabolas being alike and uniformly spaced along B'B.

INSTRUMENTAL PROPORTIONS.

It will be interesting to note the results of a few particular relations between the Instrumental Constants. In doing so c will still be regarded as plus, and a as the natural unit of the instrument, which will be represented in simple special positions, A being supposed to make one complete circuit of the different circular areas shown.

Case I. $a = 1$; $c = b = o$.

This supposition is illustrated in Fig. 16, and corresponds to the origin of co-ordinates in Fig. 15. It is a more elegant supposition to make VC, the Radius-Bar, of infinitesimal length in order that the instrument may retain all its parts, with the angles θ and β, and be governed by the same laws as have been formulated. The result is the same, however, as to the capacity of the instrument, which is now restricted to the measurement of a circle of radius a. As the Wheel-Plane passes through C the wheel does not revolve and the formula becomes for $n = 1$,

$$A = A_0 + K = A_0 = \pi,$$

so that the radius r_0 is a = unity, or $r_0^2 = 1$, as indicated in Fig. 15, and A traces the o-Circle.

In tracing the circle we must regard the value of β as constant, so that the infinitesimal Radius-Bar also revolves, the instrument revolving as a whole around C, otherwise Prop. III. will be violated, inasmuch as β will not return to its initial value while θ will, thus making $n = o$ and eliminating the o-Circle from the value of A. The importance of this will still further appear when we discuss Figs. 39 and 40.

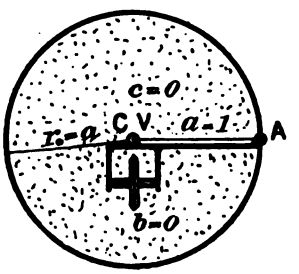


FIGURE 16.

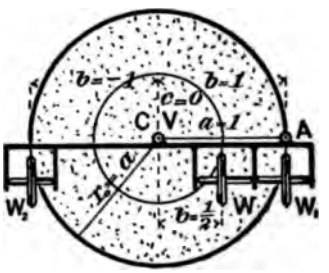


FIGURE 17.

Case II. $a = 1$; $2b = -2, 1$ and 2; $c = 0$.

For these values $r_0^2 = 3$, 0 and -1 times π, respectively, as may be seen in Fig. 15. These three cases are shown in Fig. 17, combined in one planimeter, whose Radius-Bar is infinitesimal and whose Measuring-Bar is furnished with the three wheels W_2, W and W_1, each measuring off a distance as the instrument revolves. For $b = 1$, W_1 evidently measures off the circumference described by A; for $2b = 1$, it measures half that distance, or the circumference of the smaller circle; and for $b = -1$, it measures the larger circle in the minus direction. Therefore in

$$A = nA_0 + R$$

$n = 1$; $R = -2\pi$, π or 2π and $A = \pi$, from which there results for A_0 the respective values

$$A_0 = 3\pi,\ 0 \text{ and } -\pi,$$

as already stated.

The reason for the plus and minus values of A_0 is clear when it is seen that when b is half of a the wheel measures off the mean, or middle, length of a circular strip or annulus of

width a, in which light the circular area may be regarded. Moving the wheel to the right causes it to measure off too much, so that the result needs to have a minus Zero-Circle to correct it, while if the wheel be placed farther to the left its Reading will be diminished, and even made minus, so that a plus circle is needed. These Zero-Circles cannot, however, be drawn with the instrument.

It should also be observed that the particular value, $2b=a$, has been used in Fig. 5, and referred to under AREAS AS ANNULI.

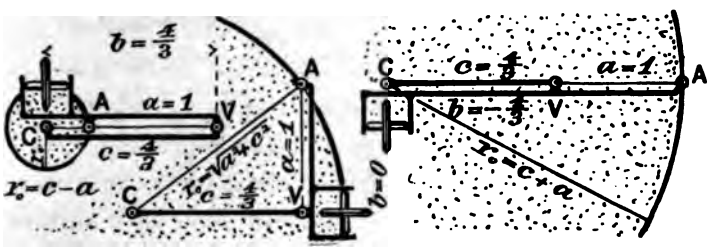


FIGURE 20. FIGURE 19. FIGURE 18.

Case III. $a=1$; $b=-c$, o and c; $o<c<\infty$.

These suppositions are shown in Figs. 18, 19, and 20. It is evident that here the wheel will not turn, so that R will disappear from the formula, leaving for $n=1$,

$$A=A_0.$$

These three figures illustrate the case of Instrumental Possibility. For $3b=-4$, o and 4, as shown, the areas of the o-Circle are respectively, as may also be seen in Fig. 15,

$$A_0=\frac{49}{9}\pi,\ \frac{25}{9}\pi \text{ and } \frac{1}{9}\pi,$$

the radii being

$$r_0=c+a,\ \sqrt{c^2+a^2} \text{ and } c-a,$$

which here $= \frac{7}{3},\ \frac{5}{3}$ and $\frac{1}{3}$.

A less value for b than $-c$ throws the wheel to the left of C in Fig. 18 and makes the Reading minus, so that a o-Circle of greater and greater area is needed as b decreases. In Fig.

20, however, positions of the wheel to the left of C give plus Readings, and as these increase with increase of b the o-Circle must diminish to zero and then become minus.

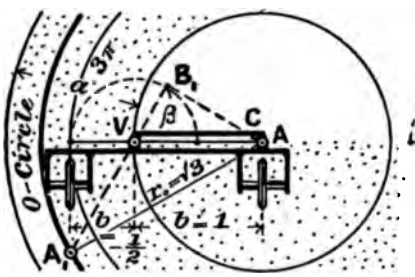


FIGURE 21.

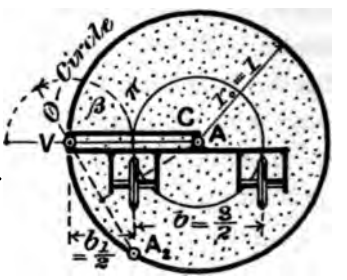


FIGURE 22.

Case IV. $a=1$; $2b=-1$, 1, 2, and 3; $c=1$.

For $b=1$ this is a special case of the preceding. As $c=a$ the Stylus describes an infinitesimal circle when the instrument is closed, consequently the o-Circle must have such an area as will neutralize the Reading of the wheel. For the first two values of b the Reading will be minus, for the third it will be zero, and for the fourth, plus. This can be seen in Figs. 21 and 22, each of which shows a planimeter with two wheels on its Measuring-Bar, corresponding with two of the above values of b.

Comparing these with Fig. 15, it appears that when

$$2b=-1, \quad R=-3\pi \text{ and } A_0=3\pi$$
$$2b=\ 1, \quad R=-\ \pi \text{ and } A_0=\ \pi$$
$$2b=\ 2, \quad R=\ \ 0 \text{ and } A_0=\ 0$$
$$2b=\ 3, \quad R=\ \pi \text{ and } A_0=-\pi$$

In the closed positions shown $\beta=180°$ and A is in position to describe the zero o-Circle for $b=1$, as illustrated by the right-hand wheel in Fig. 21. The distance of the left-hand wheel from V is $b=$ minus one-half, and the corresponding o-Circle is drawn with a radius $r=\sqrt{3}$ and shaded below the horizontal diameter. Above this the shading is applied to the annulus measured by the wheel, of length 3π and width a, and therefore having the same area numerically as the o-Circle.

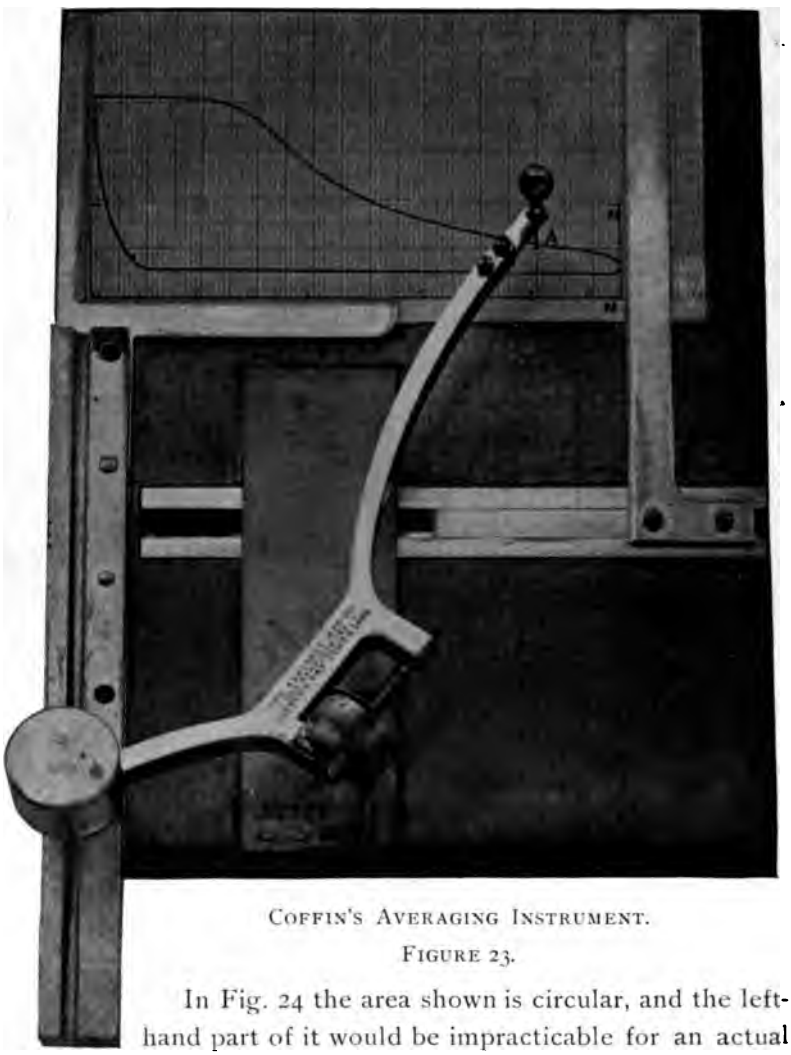
In Fig. 22 the wheels, at b = one-half and b = three-halves, give the same readings with opposite signs. The left-hand wheel gives the minus reading and the corresponding plus o-Circle is shown. This circle may be regarded as an annulus of width a, with an infinitesimal hole at the centre C, and the wheel measures its mean length π in a negative direction. The right-hand wheel also measures this annulus, but in a positive direction; so that, although the o-Circle, being minus, cannot be drawn, its area clearly enough exists. The positions of the instrument, with Wheel-Plane passing through C, and Stylus upon the o-Circles at A_1 and A_2, are shown dotted.

Case V. $c = \infty$.

Coffin's Averaging Instrument.

This case is the basis of a modification of the planimeter, in which the Radius-Bar disappears and is replaced by a rectilinear groove in a metal plate. This is seen at the left of Fig. 23 in a vertical position; it corresponds with a portion of the now infinite o-Circle, and is represented in Fig. 24 by the line MN. The Hinge is nothing more than a conically pointed pin at V, which runs in the groove; it is mostly concealed in the figure, however, by the weight which is placed over it to keep it in better contact with the sides of the groove.

In using this instrument, n is always zero, so that A_0, now infinite, disappears from the formula. In Fig. 23 it is shown engaged upon an area placed in such a position that part of its boundary is on the o-Circle; if, then, after the circuit of the boundary has been made, and the final Reading R_2 noted, the Stylus be placed at M, with the reading R_2 unchanged, and moved up along the metal guiding-strip until R_2 returns again at N to the initial reading, R_1, the distance MN will be the width, or height, of a rectangle of the same length and area as the curve, so that MN is the *mean height* of the curved area. If this area is an indicator-card, the vertical ordinates of which represent pressures, then MN will be the *mean pressure*.



COFFIN'S AVERAGING INSTRUMENT.

FIGURE 23.

In Fig. 24 the area shown is circular, and the left-hand part of it would be impracticable for an actual instrument. Theoretically, however, such an area can be measured; but while DMA may be described with V stationary at the centre of the circle, AND must be passed over in the manner shown by the dotted position of the Measuring-Bar, so that β may *return* to its initial value.

MEAN-WIDTH PLANIMETER.

The Mean-Width, or Mean-Pressure, Planimeter shown in Fig. 23 depends for its action on the fact that, on account of the infinite value of c, the co-ordinate system of the planimeter degenerates into the common rectangular system with elementary strips of uniform width, so that the rectangle, Fig. 23, being made up of such elements, is measured by the wheel as the Stylus passes over the line NM.

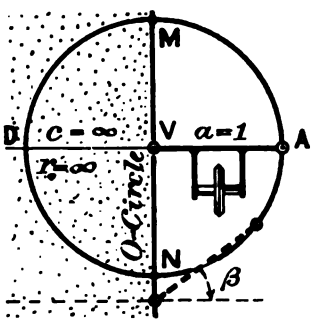


FIGURE 24.

Although in an ordinary planimeter the elements are of such a shape that a rectangle cannot be formed of them, the instrument may yet be made into a Mean-Width Planimeter by giving it an adjustable Measuring-Bar. Thus the instrument shown in Fig. 2 is made so that the Measuring-Bar may be altered in length by sliding it through the frame holding the Measuring-Wheel. The two points projecting upward are placed, one on this frame and one on the bar, so that their distance apart is equal to the length a of the latter, and the slow-motion screw and clamp at the extreme left of the bar furnish a means of adjusting the length with precision.

Now it is evident from the general equation for an area that if a be made equal to the length thereof we shall have:

$$\textit{Mean width} = A \div a = a\,R'' \div a = R'';$$

so that the difference R'' of the Readings R_2'' and R_1'' is thus made to give directly the mean width of the area in inches.

The adjustable Measuring-Bar is also utilized to adapt the planimeter to different units of measure, and the figures seen engraved upon the bar in Fig. 2 facilitate such an adjustment. Fig. 25 shows this graduation more plainly, and Fig. 26 is the different graduation of a similar instrument. The explanation of the graduations will now be given.

PLANIMETRIC UNITS.

It has already been stated that a is the natural linear unit, or *unit of length*, for the instrument; it has, however, for a subordinate linear unit, or *unit of breadth*, the circumference w of the Measuring-Wheel, and the rectangle of these two linear units is the natural *unit of area.*

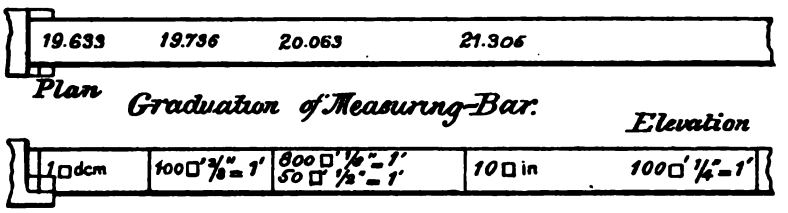


FIGURE 25.

When the Measuring-Bar is set so that the vertical line on the "elevation" marked "10 □ in" agrees with a line on the right-hand end of the wheel-frame, nearly over the Hinge,

$$a = 4 \text{ inches}$$

very nearly, so that in Fig. 25, were the whole of the Measuring-Bar shown, the Stylus would be not far from four inches to the right of this vertical line.

The fixed constants for this instrument are very nearly

$$b = -1.5 \text{ inches}$$

$$c = 6.32 \text{ inches.}$$

or, say $c^2 = 39.8$

and the circumference of the Measuring-Wheel

$$w = 2.5 \text{ inches},$$

so that the unit of area for this setting of the Measuring-Bar is

$$aw = 4 \times 2.5 = 10 \text{ □ in.}$$

as marked beside the vertical line. The area of the 0-Circle is

$$A_0 = \pi (a^2 + c^2 - 2ab)$$

$$= 3.1416 (16 + 39.8 + 12 = 67.8)$$

$$= 213 \text{ □ in.} = 21.3\, aw.$$

This number is marked on the "plan" above the vertical line.

When an area is measured the readings R_1 R_2 must be expressed as so many revolutions and parts thereof, *i. e.*, as so many times w; R will then be similarly expressed. If, now, the Needle-Point C is within the curve, so that A_0 is to be added to R, it also must be expressed in terms of w, and there results, when C is without,

$$A = R,$$

and

$$A = A_0 + R = 21.3 + R$$

when C is within, all in terms of the natural square unit aw, so that

$$aw\,(A = A_0 + R) = \text{area in } \square \text{ inches}.$$

Thus it appears, that instead of engraving upon the Measuring-Bar the area of the o-Circle as *213* sq. in., it is quite correct to express it as *21.3 aw*, and it will be found that by so doing there is a gain in convenience.

The next line is one inch farther to the left, or not far from five inches to the left of the Stylus, and is accompanied by the double legend "*800* $\square'$ $\frac{1}{8} = 1'$," and "*50* $\square'$ $\frac{1}{2} = 1'$," which is to a certain extent ambiguous and incorrect, as will be seen.

Here

$$a = 5 \text{ inches}$$

and

$$aw = 12.5 \square \text{ inches}.$$

But one square inch equals four square half-inches or sixty-four square eighth-inches, therefore

$$aw = 12.5 \times 64 = 800 \square \text{ eighth-inches},$$

or

$$= 12.5 \times 4 = 50 \square \text{ half-inches},$$

i. e., the area aw measured by one revolution of the wheel is equal to *800* squares one-eighth of an inch on the side or *50* squares one half-inch on the side. The legends should therefore preferably read "*800* $\square$ $\frac{1}{8}''$" and "*50* $\square$ $\frac{1}{2}''$," omitting the "$'$" and the "$= 1'$."

Also, the area of this o-Circle is

$$A_0 = \pi\,(a^2 + c^2 - 2ab)$$
$$= 3.1416\ (25 + 39.8 + 15 = 79.8)$$
$$= 250.1 \square \text{ in}.$$

Dividing this by the unit aw, *i. e.*, by *12.5* sq. in., there results

the area of the Zero-Circle expressed in natural units,

$$A_0 = 20.06\ aw,$$

which is the number engraved on the upper side of the bar.

When an area has been measured and R obtained, it will be so many revolutions and parts thereof, and will therefore mean that the curve, when C lies without, contains awR units of area, *i. e.*, $12.5\ R$ square inches, or $50\ R$ □ half-inches, or $800\ R$ square eighth-inches. To this must be added, when C lies within, the 20.06 units of area of the 0-Circle, thus giving for C without:

$$A = R$$

and for C within:

$$A = A_0 + R = 20.06 + R$$

all in the natural square unit $aw = 12.5$ sq. in., so that

$$aw\,(A = A_0 + R) =$$

$$12.5\,(20.06 + R) = \textit{area in } \square \textit{ inches},$$

or $$50\,(20.06 + R) = \textit{area in } \square \textit{ half-inches}$$

or $$800\,(20.06 + R) = \textit{area in } \square \textit{ eighth-inches}.$$

The object of the legends, as they appear, is simply to suggest that if the area measured happens to be on some plan or map, the scale of which is either one eighth or one half-inch to the foot, so that the actual size of the plan is either twenty-four or ninety-six times smaller than the size of the actual field or other surface represented by the plan, then the number of square feet in the actual field is the same as the number of square half-inches or square eighth-inches in the plan, and that therefore the area of the actual field is either

$$50\,(20.06 + R)$$

or $$800\,(20.06 + R).$$

The simplified legend above suggested is, however, all that is necessary, because any other reduction may without error be substituted for the one given, thus if the map is drawn to the scale of one half or one eighth-inch to the yard or rod, the above expressions give the number of square yards or square rods in the field.

But the legend may advantageously, perhaps, be further simplified, and thus generalized, by noticing that any scale can be expressed as *one inch* to something, thus: half or one-eighth of an inch per foot is one inch to two feet or eight feet, so that the legend might be simply "12.5 □ in." The area

$$aw\ A = aw\ (A_0 + R)$$
$$= 12.5\ (20.06 + R)\ \square\ in.$$

of the map is therefore also the actual area of the field expressed in square fields of either two or eight feet on the side, according to the scale, and this area is to be expressed in square feet by the ordinary rule for such cases, *i. e.*, by multiplying by 2^2 or by 8^2, the numbers in the actual legend being nothing more than 12.5×8^2 and 12.5×2^2.

The next vertical line is five-eighths of an inch farther to left, so that

$$a = 5.625\ inches$$

and $$aw = 14.06\ \square\ in.,$$

which is the simplified legend;

or $$= 14.06 \times 8^2 \div 3^2 = 100\ \square\ three\text{-}eighths\ in.,$$

i. e., *100* squares three-eighths of an inch on the side, which is the meaning of the legend as it stands.

The area of the Zero-Circle is

$$A_0 = \pi\ (a^2 + c^2 - 2\ ab)$$
$$= 3.1416\ (31.64 + 39.8 + 16.87) = 277.5\ \square\ in.,$$

or, dividing by aw,

$$A_0 = 19.74\ aw,$$

which is engraved upon the upper face of the bar.

For the next vertical

$$a = 6.2\ in.,$$

and $$aw = 15.5\ \square\ in.$$
$$= 1\ \square\ dcm,$$

which is the legend. The extreme end of the wheel-frame is shown at the left in Fig. 25, and this vertical appears in coincidence with the setting-mark upon the frame.

Also, the area of the Zero-Circle

$$A_0 = \pi\ (a^2 + c^2 - 2ab)$$
$$= 3.1416\ (38.44 + 39.8 + 18.6) = 304.4\ \square\ in.$$
$$= 19.63\ aw$$

which is seen upon the bar.

For the vertical line to the right

$$a = 1.5 inches$$

and $$aw = 6.25\ \square\ inches$$

or $$= 6.25 \times 4^2 = 100\ \sqsubset\ quarter\text{-}inches,$$

which is the legend upon the bar.

Also, the area of the Zero-Circle

$$A_0 = \pi(a^2 + c^2 - 2ab)$$
$$= 3.1416\ (6.25 + 39.8 + 7.5) = 168.3\ \square\ in.$$
$$= 26.93\ aw.$$

An examination of the legends, which can be seen upon the Measuring-Bar of the planimeter in Fig. 2, may show some slight variations from the values which have just been calculated. Fig. 25 with the Instrumental Constants used above were possibly not taken from the instrument shown, but from a duplicate, which can scarcely be expected to have exactly the same constants as the other.

The Measuring-Bar, too, is not set to correspond with a legend, but is supposed to be adjusted to a special length.

It should also be borne in mind that the instrument is liable to injury, which may render the legends inexact; indeed, for accurate work, they should be carefully tested.

The graduation shown in Fig. 26 may be verified in the same manner after obtaining the Instrumental Constants from the instrument itself. Inasmuch as the wheel is of a slightly different diameter, the lines do not correspond exactly with those in Fig. 25. The unit of breadth in this instrument has been taken as $w \div 1000$, which corresponds with the unit of the vernier, inasmuch as the wheel is divided into one-hundred parts, and the vernier divides each part by ten. This makes the natural unit

of area a thousand times smaller than in Fig. 25, so that instead of "*10 □ in.*," "*1 □ dcm*," etc., we have the one-thousandth part of those units, or "*.01 □ in.*," *10 □ mm*, etc.

The values of A_0, however, being now expressed in smaller units, appear, roughly speaking, one thousand times greater.

The legend "*.002 ac 1 : 1000*" means that for that value of *a*, the unit of area of the instrument, or $aw \div 1000$, is two one-thousandths of the thousandth part of an acre, *i. e.*, two one-millionths of an acre.

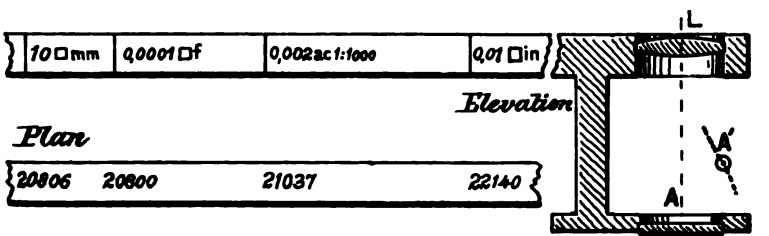


FIGURE 26.

SYMMETRICAL STYLUS.

The ordinary Stylus, in the form of a conical point, has the disadvantage that it interferes with a complete and symmetrical view of the boundary line. To obviate this difficulty in a series of accurate measurements of test areas, Professor D. S. JACOBUS has devised and made use of a transparent Stylus. This is shown in section in the elevation Fig. 26, some three inches of the Measuring-Bar being broken away to bring it within the limits of the drawing.

As may be seen, the point of the Stylus is replaced by a glass disc A, with a suitable mark upon it, and the vision is still further assisted by the lens L. A′ shows such a mark in plan, the dotted line representing a portion of the boundary as seen beneath it. This unobstructed, symmetrical, and magnified view enables the operator to follow the boundary with an exactness unattainable with the ordinary Stylus.

When the lower side of the glass disc is flat it becomes somewhat scratched by use, and it might therefore be better to

make it of such a shape as to avoid this. Thus the lower face might be ground more or less conical, so that only the central point could come in contact with the paper. The lower face of the disc might also be made slightly convex, with the central portion somewhat concave, leaving a ring in contact with the paper just outside of the small circle and dot shown at A′.

ARGON—THE NEW ELEMENT.

BY PRESIDENT HENRY MORTON.

IN a paper recently presented to the Royal Society by Lord Rayleigh and Prof. Ramsay, there was announced the discovery of a new element, existing as a constituent gas of the ordinary atmosphere.

Attention was first directed to the line of research which led to this discovery by observing that the density of nitrogen gas prepared from the atmospheric air by processes involving the absorption of everything else was always greater (by about ½ per cent.) than that of the same gas when obtained by decomposing chemical compounds containing it.

Precautions having been taken and experiments made which excluded the presence of accidental impurities, the only solution remaining was the assumption that in the atmosphere there was present, in addition to its heretofore known constituents, a new gas, heavier than nitrogen, but so far resembling it in properties as to accompany it and remain with it when it ran the gauntlet of the various absorbents.

The next thing was to separate this close companionship and secure the new elemental gas in a free or separated state.

This separation was effected in two ways:

1st. By passing nitrogen, obtained from air by absorption of oxygen and all other known constituents, over red-hot magnesium, which absorbs the nitrogen but does not act on the new element.

2d. By removing the nitrogen from air by exposing it, in presence of excess of oxygen and an alkali, to a continued discharge of electric sparks. Curiously enough, this method was employed by Cavendish in 1785 (see Philosophical Transactions of the Royal Society for 1785, p. 372); and he found a residual portion of gas left, which he could only account for as an accident of the experiment, such as lack of purity in materials or the like.

The same explanation has been given down to the present time, although, as would now appear, Cavendish had actually isolated the new element in 1785.

The most characteristic property of the new element seems to be its inertness or absence of affinity for any other substance.

Nitrogen has been regarded as the leading element in this direction, as is implied in its French name, "Azote," which appears also in English and in many derived English words, such as "azotized," "azotic"; but the new element, which has been named Argon, far surpasses nitrogen in its negative character. In fact, so far it has been found impossible to combine it with anything, and therefore the determination of its molecular or atomic weights by direct means is impossible at present.

It is, however, estimated that its atomic weight may be either 20 or 40, its specific gravity, compared with hydrogen as unity, being 19.9.

Its solubility in water is about two and one-half times as great as that of nitrogen. Its spectrum under the electric discharge is distinctive, and is different in a marked degree from that of nitrogen.

As reported so far, the conditions of its liquefaction by cold and pressure do not greatly differ from those of nitrogen.

It is certainly remarkable that a substance existing in the atmosphere in appreciable proportions, and constituting, in the aggregate, an enormous quantity, should have escaped all recognition until the present time.

TESTS OF AUTOMATIC SPRINKLER HEADS.

SECOND PAPER.

BY PROFESSOR D. S. JACOBUS.

AT the close of the first paper on this subject mention was made of tests of heads that had been in use for a considerable period of time. Many tests of this kind have been made by us, which indicate, as stated in the first paper, that various defects are found in old heads which do not exist in heads which are new. The defects, as already stated, are:

1st. The failure of the releasing device to open in heads which rely in a great measure on the elasticity of the brass frame, or other stiff brass pieces, to throw apart the solder joint after the solder has melted.

2d. Corrosion at the valve and seat, which may cause the valve to stick to the seat after the solder joint has melted and the releasing device has opened.

3d. The sprinklers may open of their own accord without the application of heat.

In addition to the above defects, it is sometimes found that the fusible solder hardens with age. These conclusions were drawn from the results of tests made at various times during a number of years, and, as they tended to show that an automatic fire sprinkler may be a very unreliable device, we made the suggestion to the New York Board of Fire Underwriters that a number of old sprinkler heads of different patterns be taken from various plants and forwarded to us for testing. These tests are now under way, and the results of those already completed show that many heads are extremely unreliable after they have become corroded.

Before receiving the old heads forwarded to us by the New York Board, we made a series of tests on a number of old heads that were in our possession. Some of the heads were corroded and others were not. The most instructive results were obtained from a series of tests on heads that had been exposed to circumstances which, in most cases, produced severe corrosion. We will, therefore, consider the results of this series only.

The sprinkler heads on which this series of tests were made had been connected to piping and subjected to corrosion for from four to nearly seven years. The piping to which these heads were connected was in short lengths, which were filled with water and with salt and water.

During the interval that the heads were subjected to corrosion many opened of their own accord without the application of heat, and in others pieces of the releasing device had become bent out of shape.

All the heads which had not opened of their own accord were tested by placing them in an oven which was heated by a large Bunsen gas-burner, as explained in the first paper; but, instead of maintaining the oven at a constant temperature and noting the time required to set off the heads, which gives a measure of their relative sensitiveness, they were heated gradually to the temperature of about 380° Fahr., in order to copy more nearly the conditions which exist in the case of a fire. The oven was heated at such a rate that the maximum temperature was reached in about four minutes. The pressure of water on the sprinkler heads was that equivalent to 10 feet of head. The oven was maintained at the maximum temperature until the head opened or until 15 minutes had elapsed, which demonstrated that the head was defective. At the end of this time the water-pressure was increased until the sprinkler head opened, or until it reached the pressure of about 40 pounds per square inch. If a pressure of 40 pounds per square inch was reached without opening the sprinkler, the latter was removed from the

oven and the solder joint piece was forced apart to note if the solder had hardened, and to see if the pieces of the releasing device would spring enough to tend to throw the joint apart; or the sprinkler was placed directly in the flame of a large Bunsen gas-burner. In most cases of failure it was found that there was no elasticity remaining in the releasing device.

These tests were made with great care by Prof. Anderson, and the following results were obtained:

1st. Only 20% of the entire number of heads operated perfectly.

2d. In 50% of the heads there was no elasticity remaining in the pieces relied upon to throw apart the solder joint and releasing device.

3d. In about 35% of the heads the valves stuck fast to the seats.

4th. In about 45% of the heads the solder joint had become hardened.

5th. About 15% of the total number of heads opened of their own accord, without the application of heat. This difficulty was, however, confined to two forms of heads.

A summary of the tests in the heated oven is given in Table I. Table II. shows the condition of the heads after having been connected to the piping for the time already specified.

We have been told that the presence of mercury in the fusible solder tends to harden it after a long period of use. We therefore preserved samples of solder from each form of head and submitted the same to analysis. The analyses were made by Prof. Stillman and show that mercury was present in some cases where the solder hardened, but not in others. Column 11 of Table I. shows which heads employed solder that contained mercury.

All the solder joints in which we found that the fusible solder had hardened were formed by soldering two brass pieces together by means of the fusible metal. It may be that an

TABLE I.

Summary of tests of sprinkler heads which were connected to short lengths of piping filled with water and with brine, and allowed to stand in this condition for from four to six and three-quarters years. The heads were in most cases severely corroded. The tests were made by placing the heads in an oven, which was heated until it reached the temperature of about 380 degrees Fahrenheit, after which it was maintained at this temperature until the head opened, or until it was demonstrated that the head was defective. The time required to heat the oven to the maximum temperature was about four minutes.

CLASS OF HEAD.	Number of years that the heads were connected to piping and subjected to corrosion.	NUMBER OF HEADS. TESTED.	That failed to release in oven in 15 minutes.	That failed to release in the flame of a Bunsen burner for one minute.	That released perfectly in oven in less than five minutes.	With no elasticity in the releasing device.	In which valve stuck to the seat after the releasing device opened.	In which valve was held to the seat by a piece of the releasing device after solder joint melted.	In which the fusible solder had become hardened by age.	Heads in which an analysis of the solder indicated that mercury was present.
1	2	3	4	5	6	7	8	9	10	11
A	4	1	1	...	0	...	...	1	...	...
B	5	1	0	...	1	...	...	...	...	Contains Mercury.
C	4½	1	1	...	0	...	1	...	...	No Mercury.
D	6¾	3	3	2	0	3	3	...	3	Trace of Mercury.
E	5¾	7	3	...	3	3	1	2	3	Contains Mercury.
F	4½	6	4	...	0	4	2	...	3	No Mercury.

TABLE II.

Summary giving the condition of heads after having been connected to short lengths of piping and subjected to the action of water and of brine for a number of years.

Class of Head.	Number of years that heads were subjected to corrosion, and were under our observation.	NUMBER OF HEADS.			
		Examined.	Apparently unimpaired.	IMPAIRED.	
				Releasing device open.	Bars bent, or valve partially released.
1	2	3	4	5	6
A	4	1	1	...	...
B	5	5	1	3	1
C	4½	4	1	2	1
D	6¾	4	...	...	4
E	5¾	7	7	...	...
F	4½	6	6	...	...

action takes place between the brass and solder, which, combined with the effect of corrosion at the edges of the joints, tends to harden the solder, or to cement one brass piece to the other.

The fact that so many of the sprinkler heads operated imperfectly shows that many of the present forms of heads should not be used in positions where they may become corroded. Every sprinkler head that is placed in position where it may become corroded, or incrusted with a foreign material, should possess the following features in addition to those enumerated for a successful head in the first portion of this paper:

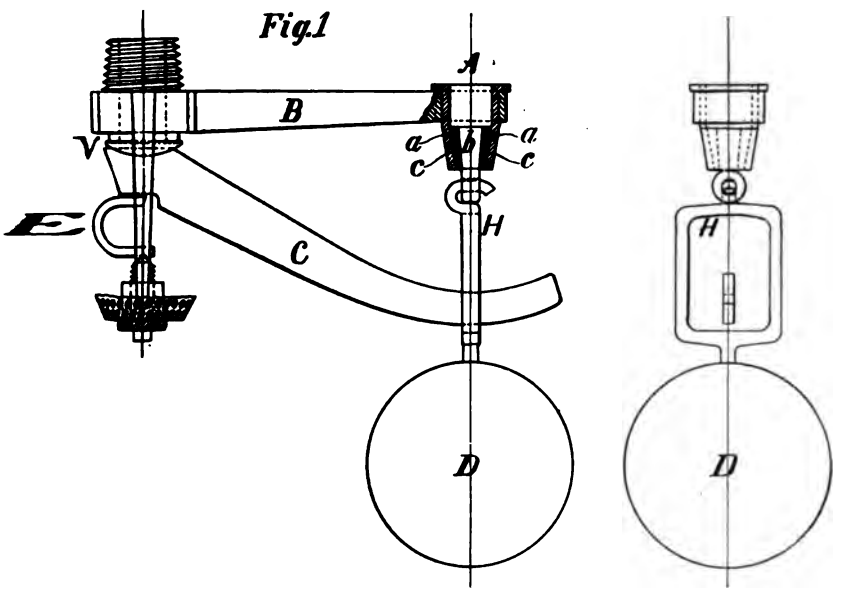
1st. There should be some device, not subject to corrosion or affected by age, which will tend to force open the solder

joint and throw apart the releasing device when the fusible solder has melted.

2d. The valve should be forced from the seat after the releasing device has opened by some means other than that produced by the pressure of the water against the valve.

We have devised several heads to meet these requirements, and have submitted the designs to the New York Board, in the hope that some of the sprinkler companies will make use of the principles involved, and manufacture a sprinkler head that will open, no matter how greatly it has become corroded. The general principle involved is to make use of a weight which will fall when the solder melts, and will release and force open the valve. One of the designs is shown in Fig. 1.

Fig. 1



In this the solder joint piece A rests on the arm B, which projects from the body of the sprinkler head. The solder joint piece A supports the weight D. The valve V is fastened to the lever C. E is a spring to hold the valve against the seat. The

weight D is supported by two vertical pieces which pass on each side of the lever C. When the solder piece melts, the weight D falls, and the cross-piece H, below the supporting hook, strikes the lever C and opens the valve. If the head is provided with a flexible diaphragm valve-seat, a straight post may be used in place of the spring E. The weight D should be attached to a chain to prevent it falling to the floor.

It is probable that with either the ordinary soldered brass or fusible metal links the action of the weight will tend in time to break the link without the application of heat. We have therefore designed, and are making experiments on, solder joint pieces in which the fusible metal is subjected mainly to a compressive stress. One form of such a solder joint piece is represented at A in Fig. 1. In this the thimble-shaped piece, a a, is held by the arm B; b is a circular piece, having an inverted cone-shaped end. The largest diameter of b is smaller than the smallest diameter of a a. The fusible solder is cast or soldered in a ring-shaped piece, c c, around the piece b and inside of the thimble-shaped piece a a. When new the joint withstands many times the force that will rupture an ordinary solder joint having the same surface, and, if the piece b is raised upward a short distance in the thimble a a, and the ring of fusible metal c c is made correspondingly longer, we reach a point at which the brass piece b will break at the lower neck with but little yielding of the ring c c.

Tests to determine the sensitiveness of these joints show that they release in less than three minutes at a temperature of 300° Fahr., which is a shorter time than that required by the average sprinkler head now on the market.

We have started a series of time tests, in which heavy weights are attached to the joints. We do not think there will be trouble with the joints yielding of their own accord, because the solder has to flow out of its position before the joint can open, and should there be such a flow of metal it would neces-

sarily be a slow action; so that if the joints were replaced from time to time—as should be done to prevent hardening of the solder—there would be no danger of accidental yielding. The time tests now under way will show definitely if our supposition in regard to the durability of the joint is a correct one.

UNIVERSITIES.

BY PROF. DE VOLSON WOOD.

A WRITER on university education, some years since, said that the essentials of a university were a learned faculty and a well-equipped library. At the present day he would have said, a learned faculty representing a great variety of subjects and well-equipped laboratories, including the library as a laboratory. The students who resort thither for instruction and drill are non-essential; they serve as the receptacles of such wisdom and knowledge as the professors may give in their lectures and conversation.

Such institutions exist in Great Britain and Europe, but, until recently, not in this country. There have been, on this side of the Atlantic for a long time, universities in name; but their instruction was of the same character as that of the college, and, too frequently, of an inferior grade. There was no provision for a faculty of specialists under whom the student, who had already passed through a course of general culture, might have the freedom of choice in the pursuit of his studies.

Among the universities of recent origin Johns Hopkins was the first to break loose from the old system and furnish a university in its true sense. Two systems were then established within one corporation—an undergraduate college and the university. The former consisted of several well-defined three-

year "courses without optionals." One was a thorough classical course, another a thorough scientific course; and, between these, were other courses, containing a mixture of classical and scientific studies. The requirements for admission to these courses were of high grade, presumed to be equivalent to those for admission to the sophomore class in most colleges, so that the acquirement at the end of the three-years' course was presumably as great as that of the ordinary four-years' college course.

The other system was the university proper, which has attracted to it many mature scholars, graduates of other colleges, and many professors in institutions of learning, scattered over a large territory.

The next—the Clark University of Worcester, Mass.—did not copy from its predecessor. It has no fixed curriculum; nor, according to our information, is it designed for students to learn what has been done, but rather to aid investigations. Students having a desire to make a scientific research will be assisted by one or more of the professors. If this be true, it would seem to conform to the idea of the university of the writer above referred to.

The next—the Leland Stanford Jr. University—has not copied from either of its predecessors. The princely fortune with which it is endowed—said to be $15,000,000—has enabled its president to select a large faculty representing the broad fields of literature, science, and technics. The palatial buildings must themselves be an object-lesson in architecture, and the tropical gardens which surround them make the scene a kind of fairy-land, which, with the comfortable and neatly furnished rooms, combine to promote esthetic culture among the students. This is not a university for post-graduates, but rather one in which a student may pursue any desirable subject. He chooses the leading subject which he desires to pursue, and is then placed in charge of the professor at the head of that department, who advises him in the choice of two other subjects, as he is required

to pursue three studies at a time. The professor under whom he is placed is more or less responsible for his conduct and progress.

The next—the University of Chicago—has its peculiarities, one of which is its endless term. It has no beginning of years, nor end of terms—no fixed course—no vacation—no commencement—no salutatory—no valedictory! The professors have their days for instruction and the students must accommodate themselves thereto. Some instruct during the summer, others in the winter. When a student has completed a certain amount of study and passed the requisite examinations he may be quietly graduated at any time during the year.

It remains to be seen what peculiarity will be attached to the next great university. It is plain that the term "university" does not convey to the mind any fixed system. A truly great university—a post-graduate institution—cannot exist and flourish without a faculty of eminent scholars, such as lead in the field of thought in their own specialties. Such an institution requires a large capital and sufficient income to be independent of students' fees. It is well said that a university cannot be made in a day; but with sufficient capital to enable it to secure such professors as it chooses and can secure, and to purchase the needed apparatus, it can go very far toward securing the two essentials—a faculty and laboratories, including a library—in a short time. Thus, the Leland Stanford Jr. university, with its large endowment, was able to secure to itself some of the best professors of other colleges; and, similarly with the Chicago University, with its $7,000,000. The latter institution is in danger of being relatively poor, if, indeed, it is not already so, on account of the very broad plan on which it is established.

We have not mentioned such universities as Harvard, Yale, Columbia, Princeton, Pennsylvania, etc., in which the chief peculiarity consists in substituting the term "university" for "college;" nor of Cornell, Michigan, and many other similar

universities whose chief peculiarities consist in uniting several colleges in one corporation. With the old college proper these usually combine a technical school and either a school of medicine or of law, or both these. They are doing a great undergraduate work. The best schools of medicine, instead of requiring post-graduation in an unprofessional school for entrance, have extended their courses to four years, so that those pursuing the course may become scholarly as well as professional.

The University of Michigan no longer has a commencement for its different schools, but one grand commencement for all its schools—of Arts, of Science, of Technics (including Engineering and Pharmacy), of Medicine (including the Allopathic and Homeopathic), of Dentistry, and of Law. There is no salutatory, no valedictory, but an address by some person chosen by the Board of Regents. Then follows the conferring of about 700 degrees, accompanied by a corresponding number of diplomas, not signed by the professors, but signed by the president and secretary of the Board of Regents.

PROGRESS IN THE COTTON FIELD.

BY WILLARD P. PARSONS, M. E., '80.

Let us first glance at the condition of the country where cotton is king and we find the land divided into large plantations sometimes worked by the individuals owning them, but in general rented to families in sections varying in size with the number of members in the family or the ability of the tenant. Throughout the old south the renters are generally negroes, who depend for all living necessities on the land owner and settle their accounts with him once a year. Through Texas and the newer cotton growing districts the negroes' place is taken by thrifty foreign emmigrants with their families, who rent from the land owner and bring their economical foreign training to bear, working their entire family during harvest time and raising such crops as can be harvested most economically. With the negro renters, prior to the present year, cotton has been almost the sole product, and they have depended on the land owners for corn and bacon. The land owner generally runs a store from which his tenants obtain all that is necessary; and, as the negro is always in debt to the store, the proprietor practically controls the whole plantation, dictating the nature of the crops and the time of harvesting. Under this system there is of course very little fertilizing done since the utilization of cotton seed for oil. In the old South the land owner generally owns the mules, renting them to his negro tenants for plowing and harvesting. One mule raises from 20 to 40 acres of cotton, according to the mule and the quality of the soil.

In preparing a field for a cotton crop, the last year cotton stalks are plowed under or burned, and the seed planted in rows from 2½ to 6 feet apart, according to the richness of the

soil. The seeds are generally planted with a machine planter, and with proper care the plants will not vary much either to the right or left of a given line. After the cotton plants appear the rows are either "chopped out" or plowed into check rows, the aim of the planter being to procure one stand at regular intervals of the most promising plant. When the rows are chopped these stands vary in their distance apart from 6 to 18 inches, but when the field is check plowed these stands are necessarily regularly spaced, but the planter has no choice in selecting the particular plant that is to form the stand. The plants are sometimes ridged, sometimes hilled, and often the field is left level, according to the ideas of the planter.

The cotton field has to be cultivated several times to remove weeds and foreign growth until the crop is finally "laid by," or considered to be in proper condition to await the maturing of the plants for the picker. The principal weeds the planter has to contend with are cockle, crow foot, or crab grass, and morning-glory vines.

When the picking season begins the renter and his family all take part. The thrifty whites begin as soon as the cotton bolls open and generally go over the field three times, as the bottom, middle, and top crops mature, while the negroes sometimes leave their picking until the crop is all matured. During the first of the picking season the cotton is picked very clean and free from trash, but, as the season progresses, and after the frosts, the boll shucks are so brittle that they get into the cotton and are sometimes purposely pulled with the lint. In the spring following good cotton years it is sometimes possible to see plowman and picker at work in the same field.

Cotton grows from one to twelve feet high, according to the seed and the quality of the soil. Low lands, along rivers and swamps, generally produce the tallest inland cotton, while a good average for upland cotton is between three and four feet high.

In gathering a crop the picker picks with both hands, and deposits the cotton in a bag suspended from his waist and shoulders. When filled, this bag is emptied in piles conveniently located, and from these the cotton is taken to the gins in wagons. The bag is quite long, and is allowed to drag on the ground behind the picker as he passes from stand to stand.

The price paid for hand picking for the season of 1894 varied from 35 to 60 cents per 100 pounds of seed cotton, according to the section of the country and the time of harvesting.

The problem of designing a machine for picking cotton has been studied by a large number of inventors, and many theories on the subject have been tested. Many inventors, trying to design a machine to gather the crop as free from trash as present hand-picked cotton, and finding upon trial that their machine picked considerable trash, or only a small percentage of cotton, have abandoned the idea as impractical, and the planter has finally begun to believe that cotton picking by machinery is a myth and the lunatic asylum the proper place for such inventors.

The first effort towards cotton picking by machinery produced a hand apparatus carried and operated by the picker. Later, power devices utilizing all known principles that might in any way apply were employed with varying degrees of success. Exhaust fans, blowers, and card cloth brushes were arranged under every conceivable form. Doubtless, some of them under favorable conditions would attain a marked degree of success, but, unfortunately, the cotton plant is so affected by the weather and by worms and insects that it presents to the ambitious inventor continually varying conditions.

The Southern Cotton Harvester Company understanding this, and adopting the theory that cotton could all be allowed to mature before harvesting any of the crop, as was and is done in certain sections of the country, undertook to construct a machine to gather all the cotton regardless of the quantity of

trash, relying on their ability to procure a machine to separate this trash. In 1892 they brought out the machine shown in Fig. 1, for which a prize was awarded at the Alabama State Fair that same year. This machine had four wheels and an iron body or frame from which the picker cradle was suspended by chains shown at (a). These chains were so fastened to the shaft (b) as to be under control of the operator through a worm and worm-gear, and by them the cage could be raised or lowered to suit any method of cultivation. The mechanism was driven through an intermediate shaft (c) by means of chains and sprockets from the rear ground wheels. The picking cradle was furnished with two rows of vertical rotating beater cylinders between which the cotton plants passed. These cylinders were composed of a series of discs or plates, each disc carrying four beater whips projecting radially and made of pliable steel wire. The cylinders were fastened to shafts, and driven through mitre gears from the top of the cradle. The front of the cradle carried an iron shoe, and an end so formed as to gather the cotton plant and present it in proper position to the beater cylinders. The bottom of the cradle was composed of a series of interlapping plates, so pivoted that the plants would open them, and, after passing through, the plates would close by the aid of a spring, thus preventing any cotton from falling on the ground. Two endless conveyor belts ran along the bottom and the full length of the cradle up to the bags (d), shown at the rear of machine. These conveyor belts were driven by two two-inch cross belts shown at (e). The sides of the cradle were closed with wire netting as shown. This cut shows the machine at work in a cotton field with low plants, a part of the beater discs being removed. As can be readily seen, the plants enter the front of the cradle, passing down between the two rows of beating cylinders, whose whips take off the cotton and throw it on the conveyor belts, by which it is taken to bags at the rear of the machine.

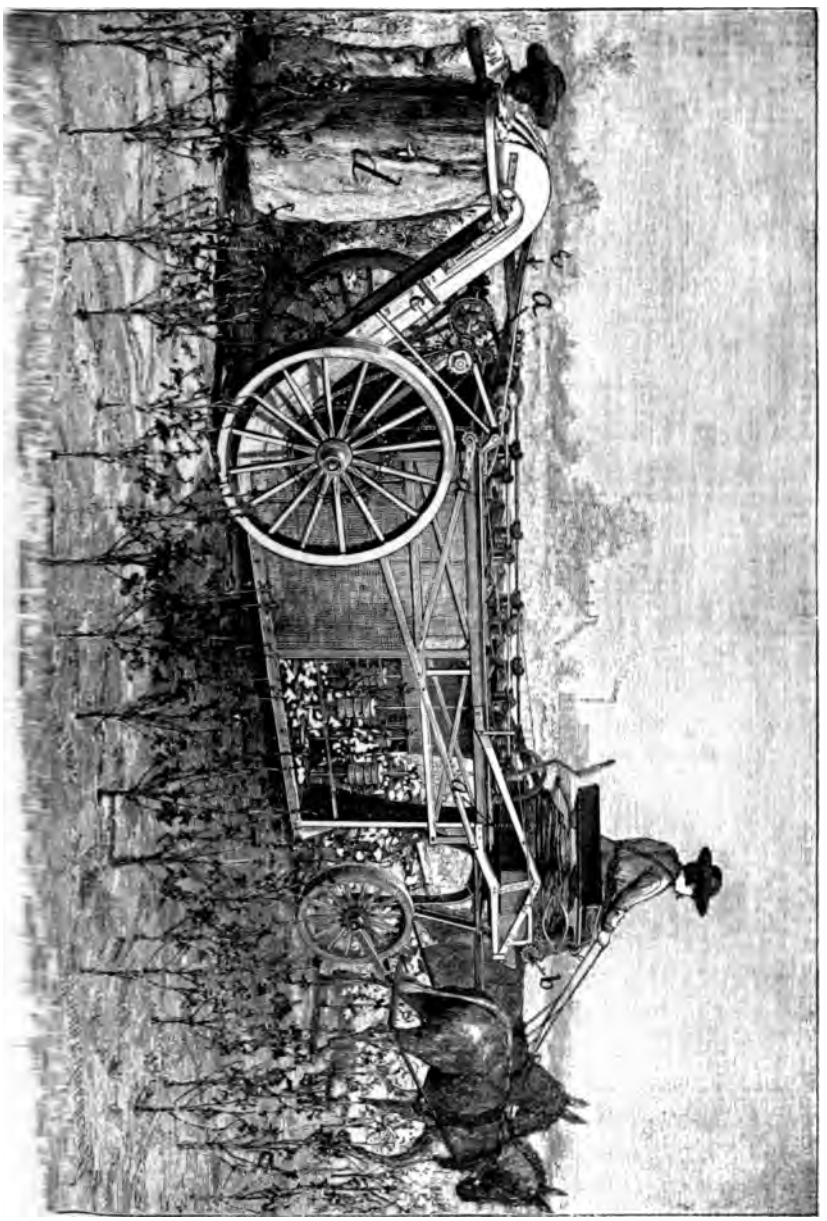


FIG. 1.
COTTON HARVESTER. PATTERN OF 1893.

When this machine was taken into the field, it was found to be full of faults, besides being too heavy and too clumsy to be handled satisfactorily.

The machine shown in Fig. 2 was brought out in 1893. This harvester was mounted on two wheels whose studs were fastened to cast-iron cross heads sliding on the main frame and controlled by a screw with its handle as shown. In this machine the beater cylinders were converted into picker cylinders. The sectional form of cylinder was retained, and

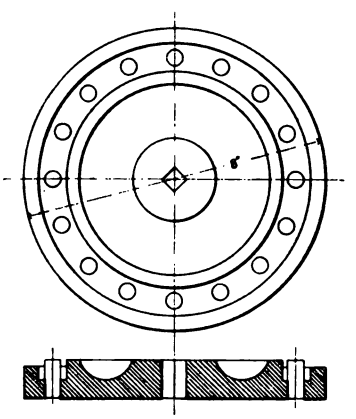


FIG. 3.

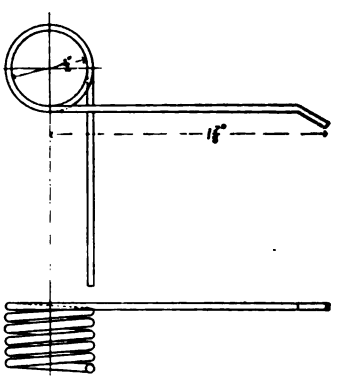


FIG. 4.

one of the sectional discs is shown in Fig. 3. The beater whips were converted into picker fingers, shown in Fig. 4. Each sectional disc carried 16 picker fingers, working on pegs shown in Fig. 3, and extending radially out side the disc about 1⅛ inches. The two single endless conveyor belts were replaced by two sets of belts arranged as in Fig. 5.

About 80% of the crop could be gathered by running this machine over the plants twice, but the remaining 20% was lost on the ground in such a manner as to make it difficult to save.

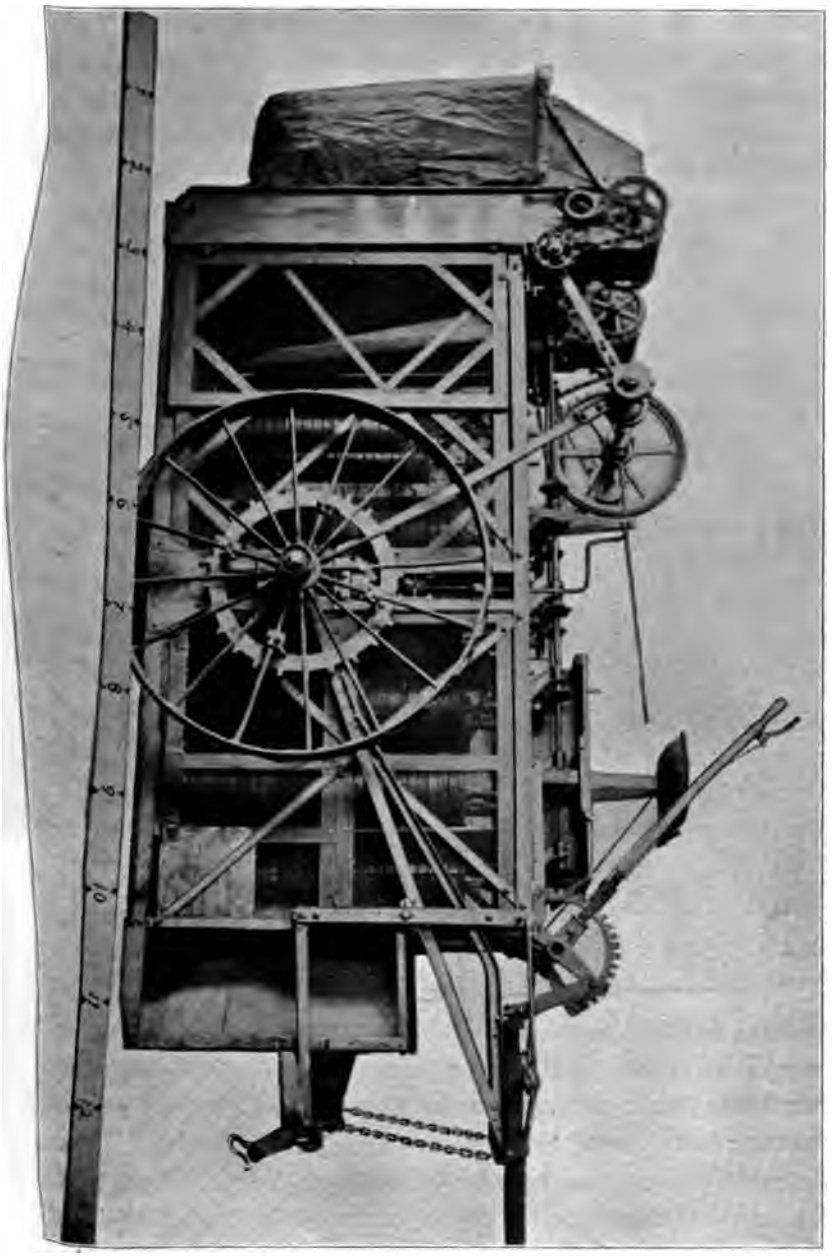


FIG. 2.
COTTON HARVESTER. PATTERN OF 1892.

Although this machine was 1000 lbs. lighter than that of '92 it was still too heavy, and the harvester shown in Figs. 6 and 7 was brought out in 1894. As can be seen, this apparatus is smaller and of lighter construction than earlier machines, but has a frame generally similar in design to the '93 pattern. The picking cylinders are arranged horizontally, and converge towards the rear of the machine. The front bearing of the

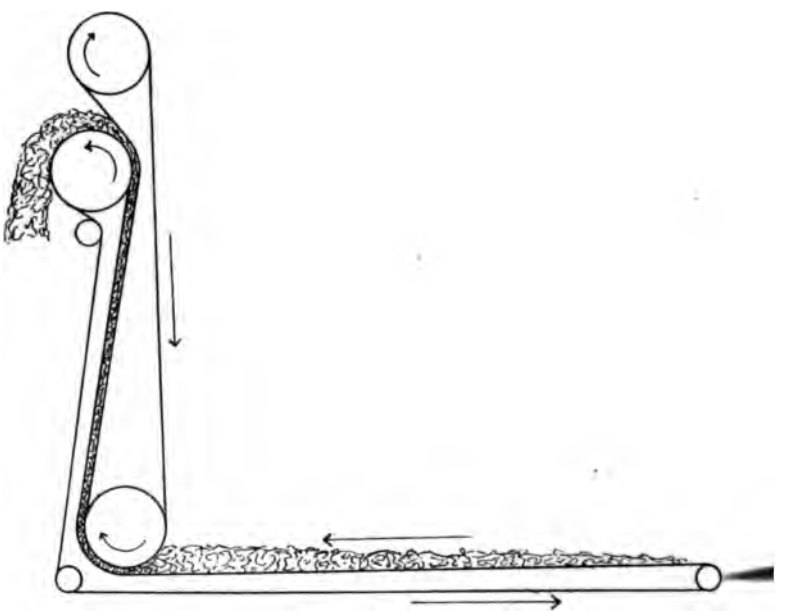


FIG. 5.

picking cylinder shaft is pivoted, and the rear bearing is a[illegible] ranged to move in and out under the control of a spring, th[illegible] regulating, in a certain measure, the pressure exerted on t[illegible] cotton plants, during their passage through the machine. T[illegible] bags at the rear of machine are discarded, and a reservoir is bu[illegible] on top of the machine for storing the gathered cotton. Th[illegible] harvester is 720 lbs. lighter than the '93 model, and with it t[illegible]

following results were obtained: The tests described have been chosen from a series of tests made in the field, while studying the mechanical effect of the different combinations of the operating parts, and were instituted solely as a basis for deciding as to the merits of the different changes. The practical finan-

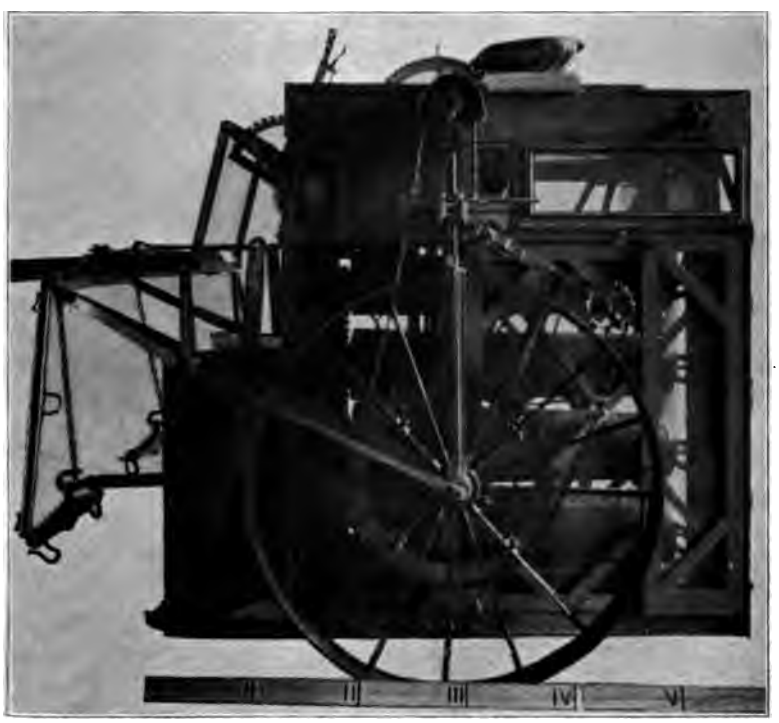


FIG. 6.

cial value of the machine can only be accurately determined by a series of trials under the varying conditions of the crop and country. However, these figures will give the theoretical capacity of the machine, and will serve to draw out an opinion on the effect of such a machine on the country.

The field in which the tests were made was level, but was planted in circular rows, four feet apart, and forming one-quarter of a circle. The rows were quite unevenly chopped, and some stands were left considerably to one side of the row. The

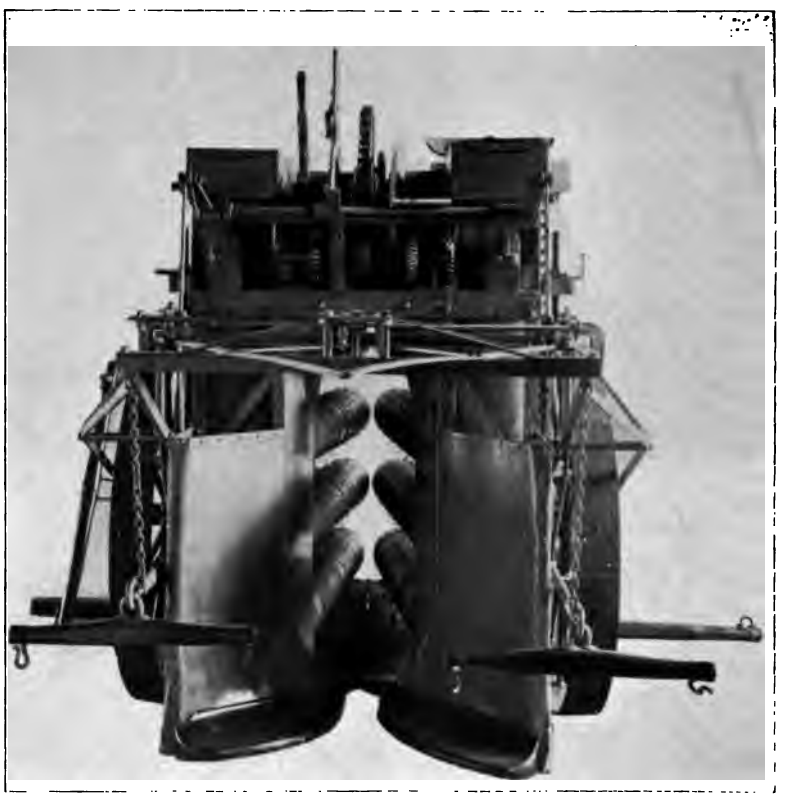


FIG. 7.

plants would average 2½ to 3½ feet high, with bottom and middle crops well matured, but with no top crop, and were ridged about eight inches. Considerable cotton had been knocked on the ground by storms, etc.

By taking one row 381 feet long and picking all cotton from the ground the machine gave the following results:

Trash and cotton picked by machine	35. lbs. net.
Picked from ground after machine	.5 lbs "
" " plant " "	1. " "
Total trash and cotton	36.5 lbs. net.

The above 35 lbs. was found to be composed of 33⅓ % of trash, therefore the

Actual cotton picked by machine weighed	23⅓ lbs.
" " lost " "	1½ "
Total cotton on row before machine ran over	24⅝ "
Or the total loss of cotton amounted to about	6%
Time in running over row 381 feet long	1 min. 27.4 sec.
Time in unloading and turning machine	1 min. 3. sec.
Time of picking one row 381 feet long	2 min. 30.4 sec

The above figures do not account for the cotton picked from the ground before the passing of the machine. To determine this time and quantity accurately, the machine was run over a row 102 feet long, without picking this storm-thrashed cotton from the ground, and it was found that it took two men 1 min. 22.4 sec. to pick all that remained from the bush and ground, and which, on being weighed, brought the total percentage of loss up to 16⅔% of cotton.

In order to determine what these figures represent, let us apply them to a two-acre field, raising one-half a bale to the acre. Supposing the rows to be four feet apart and 1037 feet long, there will be 21 rows in the two acres.

Time required to run over one row 1037 ft. long =	3 min. 58 sec.
Time unloading and turning	1 min. 3 sec.
Total time per row	5 min. 1 sec.

Or for two acres of 21 rows about 1¾ hours.

Time of two men to pick 16⅔% of the crop after machine, 4 hrs. 54 min., or say 5 hrs.; of one man, one day of 10 hours, to pick 2 acres after machine.

Now, place the value of the mules at 50 cents per day, and of their drivers at $1.00 per day, and of the laborers at 75 cents per day of 10 hours. Then for the running expense for the two acres we have:

Machine @ $1.50 per day for 1¾ hours	0.26
Labor picking after machine	0.75
" unloading and tending machine	0.13
Or the total cost of picking 1 bale or 2 acres	$1.14
As against hand picking at 40 cts. per 100 lbs	$6.00
A saving per bale of	$4.86

Out of 1500 lbs. of seed cotton picked as above we should have:

Cotton picked by machine	1250 lbs.
" " " hand	250 "
Trash " " machine	625 "
Total weight of cotton and trash to make one bale	2125 lbs.

This trash would consist of small pieces of frost-killed limbs from the cotton plant, also dried boll shucks and dried leaves. As it is necessary to separate this before ginning, it is proposed to so arrange a cleaner or separator in the gin-house that the trash will be carried to the boiler-room, to be used as fuel. The quantity of this trash can be regulated to meet the demand, between certain limits, by the tension on the picker fingers, and will become very valuable if used for this purpose, as wood is getting scarcer and dearer each succeeding year.

From the above figures, we see that a harvester could pick about 11 acres in 10 hours; or, in our assumed field of one-half bale per acre, about 5½ bales per day.

The plantation owner generally runs a gin; and, as harvesting machines will probably come under his jurisdiction, it will

be interesting to estimate what he can make out of them, on the assumption that he runs a stand of three gins capable of turning out 27 bales per day of 10 hours. To get at some value for the trash used as fuel, it may be assumed that 100 lbs. of trash furnish one horse power per hour, and that one cord of wood weighing 2700 lbs. costs $1.50, also that the trash separator requires two horse power. Let us assume that the gin stand runs 60 days during the season, ginning 1620 bales of cotton, and that the cost of additional machinery, including five harvesters, is $3000.

33.06 cords of wood @ $1.50		$49.59
Cost of picking 1620 bales by hand		9,720.00
		$9,769.59
Cost of picking 1620 bales by machine	$1,846.80	
Interest on investment @ 10%	300.00	$2,146.80
Saving by machine over hand picking		$7,612.79

This is the saving based on the actual test performances of the machine, without regard to any improvements suggested by this season's experiments, and also without making any allowance for the test performances of the operators.

By examining the foregoing figures we find it costs per bale to harvest by machinery $1.14, and of this only 0.26 is for the actual running of the machine, while 0.88 is expended for labor in correcting the faults of that machine.

It will be seen, by applying our reasoning to the harvesting of the whole cotton crop, and assuming equally favorable ginning facilities, that, in a 9,000,000 bale year, the Southern States would save the enormous sum of $42,293,253. Of course, this can never be realized under the present condition of things, as the thrifty foreign tenants could not afford to own or rent machines, while they are free to turn a large family loose on their small holdings. However, considered to-day in connection with the disturbing influences at work among the negro

laborers, and the instability of the cotton market, and the consequent desperation of the cotton planter, the discovery of a mechanical picking process is more imperatively a necessity than ever before, and the planter will more readily grasp anything to stay his continually falling fortunes; and, while the saving to the country will probably never reach the large sum mentioned above, yet it will doubtless reach a sufficient amount to satisfy the most sanguine.

As the successful introduction of these machines requires an improvement in the present cleaning capacity of most gins, the gin owner must necessarily be a party to their success, and could, under present conditions, handle the crop in any given section with a smaller number of machines and more economically than any other person. He should therefore control the machines, either by purchasing them outright, or by renting them from the manufacturers, in such numbers as to supply his gins with seed cotton, sending them out to the small planters and picking their crops at reasonable rates.

NEW THEORIES AS TO THE NATURE OF ELECTRICITY.

IN discussing electrical laws and phenomena it is usual in the vast majority of cases to employ the nomenclature and ideas of the old single or double fluid theories, while at the same time it is universally admitted that we no longer consider these theories as even remotely expressing the actual state of facts, and it is sometimes asked why we do not adopt the new theories in ordinary discussions and explanations of electrical subjects.

The best answer is, we think, furnished by a statement of the modern theories such as is furnished in the following extract from a paper entitled Modern Theories as to Electricity, by Prof. Henry A. Rowland, which recently appeared in the Engineering Magazine.

Prof. Rowland is a man eminently fitted to handle a difficult and abstruse subject, and if the exposition appears hard to master the blame must be laid upon the subject and not upon its mode of presentation.

"Modern progress in electrical theory is based upon something in the human mind which warns us against the possibility of attraction at a distance through vacant space. Newton felt this impossibility in the case of gravitation, but it is to Faraday that we must look principally for the idea that electrical and magnetic actions must be carried on by means of a medium filling all space and usually called the ether. The development of this idea leads to the modern theory of electrical phenomena.

"Take an ordinary steel magnet, and, like Faraday, cover it with a sheet of paper, and upon this sprinkle iron filings. Mapped before us we see Faraday's lines of magnetic force extending from pole to pole. We can calculate the form of these lines on the supposition that a magnetic fluid is either distributed over the poles of the magnet or on its molecules, assuming that attraction takes place through space without an intervening medium. But at this idea the mind of Faraday revolted,

and he conceived that these lines, drawn for us by the iron filings, actually exist in the ether surrounding the magnet; he even conceived of them as having a tension along their length and a repulsion for one another perpendicular to their length.

"Two magnets, then, near each other, become connected by these lines, which, like little elastic bands always pulling along their length, strive to bring the magnets together. These so-called lines of force (now called tubes of force) were, by his theory, conducted better by iron and worse by bismuth than by the ether of space, and so gave the explanation of magnetic attraction and diamagnetic repulsion.

"The same theory of lines of force was also applied by Faraday to electrified bodies, and thus all electrostatic attractions were explained. By this idea of lines of force it will be seen that Faraday did away with all action at a distance and with all magnetic and electrical fluids, and substituted, instead, a system in which the ether surrounding the magnetic or the electrified body became the all-important factor and the magnet or electrified body became simply the place where the lines of force ended; where a line of magnetic force ended, there was a portion of *imaginary* magnetic fluid; where a line of electric force ended, there was a portion of *imaginary* electric fluid. As the quantities of so-called plus and minus electricity in any system are equal, we can thus imagine every charged electrical system to be composed of a group of tubes of electrical force (more strictly electric induction) which unite the plus and minus electrified bodies, each unit tube having one unit of plus electricity on one end and one unit of minus electricity on the other. The tension along the tube explains the reason why such an arrangement acts as if there were real plus and minus electrical fluids on the ends of the tube, attracting one another at a distance. Consider a plus electrified sphere far away from other bodies. The lines of force radiate from it in all directions, and, being symmetrical around the sphere, they pull it equally in all directions. Now bring near it a minus electrified body, and the lines of force turn toward it and become concentrated on the side of the sphere toward such a body. Hence the lines pull more strongly in the direction of the negative body, and the sphere tends to approach it.

"In the case of a conducting body the lines of force always pass outwards perpendicularly to the surface, and hence, if we know the distribution of the lines over the surface, or the so-called surface density of the electricity, we can always tell in which direction the body tends to move. It is not necessary to know whether there are any attracting bodies near the conductor, but only the distribution of the lines. These lines then do away with all necessity for considering action at a distance, for we have only to imagine a kind of ether in which lines of force with given properties can exist, and we have the explanation of electric attraction.

"But the question now arises as to how the lines of electric force can be produced in the ether, or, in other words, how bodies can be charged.

"In the first place we know that equal quantities of plus and minus electricity are always produced. As an illustration, suppose it is required to charge two balls with electricity. Pass a conducting wire between them with a galvanic battery in its circuit. The galvanic battery generates the lines of force; these crowd together around it and push each other sideways until their ends are pushed down the wire and many of them are pushed out upon the balls.

"When the tension backwards along the lines of force just balances the forward push of the electromotive force of the battery, equilibrium is established. If the wire is a good conductor, there may be electrical oscillations before the lines come to rest in a given position, and this I shall consider below.

"The motion of the ends of the lines of force over and in the wire constitutes what is called an electric current in the wire which is accompanied by magnetic action around it and also by waves of electromagnetic disturbance which pass outward into space.

"If, after equilibrium is established, we remove the wire, we have simply two charged spheres connected by lines of electrostatic force and thereby attracted to each other. If we replace the battery by a dynamo or by an electric machine the effect is the same.

But there is another way by which bodies are often charged

and that is by *friction*. In this case we can suppose the glass to take hold of one end of the lines of force and the rubber the other end, and it is then only necessary to pull the bodies asunder to fill the space with lines. The friction is merely needed to bring the two bodies into intimate contact and remove them gently from each other.

"The following considerations may guide us in understanding the details of the process. It is well known from Faraday's researches that a given quantity of electricity has a fixed relation to the chemical equivalents of substances. Thus it requires 10,000 absolute electro-magnetic units of electricity to deposit 114 grams of silver, 68 grams of copper, 34 grams of zinc, etc.

"Hence we can consider, for instance, in chloride of silver that the atoms of silver are joined to the atoms of chloride by lines of electrostatic force which hold them to each other. If, by rubbing the chloride of silver, we could remove the chlorine on the rubber while leaving the silver, we could stretch them asunder and so fill space with the lines of electrostatic force. According to this theory, then, each atom has a number of lines of force attached to it, and it is only by stretching the atoms apart that we can fill an appreciable space with them and so cause electrostatic action at a distance.

"We come to the conclusion, then, that all electrification is originally produced by separating the atoms of bodies from one another, which can be done by breaking contact, by friction, or by direct chemical action of one substance on another, or in some other manner not so common. The lines of electrostatic force in a case of electricity at rest must always begin and end on matter, and they can never have their ends in space free from matter. The ends can be carried along with the matter, constituting electric convection, or they can slide through a metallic conductor or an electrolyte or rarefied gas, making what we call an electric current; but, as they cannot end in a vacuum, they cannot pass through it. Thus we conclude that a vacuum is a perfect non-conductor of electricity.

"The exact process by which the ends of the lines of force pass through and along a conductor can at present be only dimly imagined, and no existing theory can be considered as entirely satisfactory. In the case of an electrolyte, however,

we can form a fairly perfect picture of what takes place as the decomposition goes on. Thus, in the case of zinc and copper in hydrochloric acid, we can imagine the zinc plate attracting the chlorine of the acid, thus stretching out the natural line of electric force connecting the chlorine atom and the first hydrogen atom; we can imagine the atoms of chlorine and hydrogen in the body of the liquid recombining with each other and their lines of force uniting until they form a complete line long enough to stretch from the zinc to the copper plate; and all without once making a line of force without its end upon matter. We can further imagine the ends of this line sliding along the copper and zinc plates to the conducting wires and down their length, thus making an electric current and carrying the energy of chemical action to a great distance.

"If the ends of the lines should slide along the wire without any resistance, the wire would be a perfect conductor; but all substances present some resistance, and in this case heat is generated. This we always find where an electric current passes along a wire; as to the exact nature of this resistance or the nature of metallic conduction in general we know little, but I believe we are approaching the time when we can at least imagine what happens in this most interesting case.

"Besides the heating due to the electric current, steadily flowing, we must now account for the magnetic lines of force surrounding the current and the magnetic induction of one current on the other.

"If the current is produced by the ends of the tubes of electrostatic force moving along the wire, then we may imagine that the movement of the lines of electrostatic force in space produces the lines of magnetic force in a direction at right angles to the motion and to the direction of the lines of electrostatic force. At the same time we must be careful not to assume too readily that one is the cause and the other the effect; for we well know that a moving line of magnetic force (more properly induction) produces, as Faraday and Maxwell have shown, an electric force perpendicular to the magnetic line and to the direction of motion. Neither line can move without being accompanied by the other, and we can, for the moment, imagine either one as the cause of the other. However, for steady cur-

rents, it is simpler to take the moving lines of electrostatic force as the cause and the magnetic lines as the effect.

"We have now to consider what happens when we have to deal with variable currents rather than steady ones.

"In this case we know from the calculations of the great Maxwell and the demonstrations of Hertz that waves of electromagnetic disturbance are given out. To produce these waves, however, very violent disturbances are necessary. A fan waved gently in the air scarcely produces the mildest sort of waves, while a bee, with comparatively small wings moved quickly and vigorously, emits a loud sound.

"So, with electricity, we must have a very violent electrical vibration before waves carrying much energy are given out.

"Such a vibration we find when a spark passes from one conductor to another. The electrical system may be small in size, but the immensely rapid vibrations of millions of times per second, like the quick vibration of a bee's wing, sends out a volume of waves that a slowly moving current is not capable of producing. The velocity of these waves is now known to be very nearly 300,000 kilometers per second. This is exactly the velocity of waves of light, or other radiation in general, and there is no doubt at present in the minds of physicists that these waves of radiation are electromagnetic waves.

"By this great discovery which almost equals in importance that of gravitation, Maxwell has connected the theories of electricity and of light, and no theory of one can be complete without the other. Indeed they must both rest upon the properties of the same medium which fills all space—the ether.

"Not only must this ether account for all ordinary electrical and magnetic actions, and for light and other radiation, but it must also account for the earth's magnetism and for gravitation.

"To account for the earth's magnetism, we must suppose the ether to have such properties that the rotation of ordinary matter in it produces magnetism. To account for gravitation it must have such properties that two masses of matter in it tend to move toward each other with the known law of force, and without any loss of time in the action of the force. We know that moving electrical or magnetic bodies require a time represented by the velocity of light before they can attract

each other in the line joining them. But, for gravitation, no time is allowable for the propagation of the attraction.

"But the problem is not so hopeless as it at first appears. Have we not in 250 years ascended from the ideas of a viscous fluid surrounding the electrified body and protruding arms outward to draw in the light surrounding bodies to the grand idea of a universal medium which shall account for electricity, magnetism, light and gravitation?

"The theory of electricity and magnetism reduces itself, then, to the theory of the ether and its connection with ordinary matter, which we imagine to be always immersed in it. The ether is the medium by which alone one portion of matter can act upon another portion at a distance through apparently vacant space.

"Let us then attempt to see in greater detail what the ether must explain in order that we may, if possible, imagine its nature.

"1st. It must be able to explain electrostatic attraction. These electrostatic forces are mostly rather feeble as we ordinarily see them. Air breaks down and a spark passes when the tension on the ether amounts to about $\frac{1}{100}$ pound to the square inch. It is the air, however, that causes the breakdown. Take the air entirely away, and we then know no limit to this force. In a suitable liquid it may amount to 500 times that in air, or 5 pounds to 1 square inch, and become a very strong force indeed. In a perfect vacuum the limit is unknown, but it cannot be less than in a liquid, and may thus possibly amount to hundreds, if not thousands, of pounds to the square inch.

"2d. It must explain magnetic action. These actions are apparently stronger than electrostatic actions, but in reality they are not necessarily so. A tension on the ether of only a few hundred pounds on the square inch will account for all magnetic attraction that we know of, although we are able to fix no limit to the force the ether will sustain. No signs have ever been discovered of the ether breaking down.

"Again, we must be able to account for the magnetic rotation of polarized light as it passes through the magnetic field; and it can be accounted for only by assuming a rotation around the lines of magnetic force. This action, however, takes place

only while the lines of magnetic force pass through matter, and it has never been observed in the ether itself. The velocity of rotation, however, is immense, the plane of polarization rotating in some cases 300,000,000 times per second.

"The ether must also account for the earth's magnetism. If we assume that magnetic lines of force are simply vortex filaments in the ether, we have only to suppose that the ether is carried around by the rotation of the earth, and we have the explanation needed. The magnetism of the earth would then be simply a whirlpool in the ether.

"3d. The ether must be able to transmit to a distance an immense amount of energy either by means of electromagnetic waves as in light, or by the similar action which takes place in the ether surrounding a wire carrying an electric current.

"The amount of energy which can be transmitted by the ether in this manner is enormous, far exceeding that which can be carried by anything composed of ordinary matter. Thus, take the case of sun light; on the earth's surface illuminated by strong sun light a horse power of energy falls on every 7 square feet. At the surface of the sun the ethereal waves carry the energy outward at the rate of nearly 8,000 horse power per square foot.

"Again, an electric wire as large as a knitting needle, surrounded with a tube half an inch in diameter, in which a perfect vacuum has been made to prevent the escape of electricity, may convey to a distance 1,000 horse power—indeed, even 10,000 or more horse power—there being apparently no limit to the amount the ether can carry.

"Compare this with the steam engine, where only a few hundred horse power requires an enormous and clumsy steam pipe. Or, again, the amount carried by a steel shaft, which, at ordinary rate of speed, would require to be about a foot in diameter to transmit 10,000 horse power.

"When we compare the energy transmitted through a square foot of ether in waves, as in the case of the sun, with the amount that can be conveyed by means of sound waves in air or even sound waves in steel, the comparison becomes simply ridiculous, the ether being so immensely superior. As quick as light, the ether sends its wave energy to the distance

of a million miles while the sluggard air carries it one. Thus, with equal strain on each, the ether carries away a million times the energy that the air could do.

"4th. The ether must account for gravitation. For this purpose we are allowed no time whatever to transmit the attraction. As soon as the position of two bodies is altered, just so soon must the line of action from one to the other be in the straight line between them.

"If this were not so, the motion of the planets around the sun would be greatly altered. Toward the invention of such an ether, capable of carrying on all these actions at once, the minds of many scientific men are bent. Now and then we are able to give the ether such properties as to explain one or two of the phenomena, but we always come into conflict with other phenomena that equally demand explanation.

"There is one trouble about the ether which is rather difficult to explain, and that is the fact that it does not seem to concentrate itself about the heavenly bodies. As far as we are able to test the point, light passes in a straight line through space, even when near one of the larger planets, unless the latter possesses an atmosphere. This could hardly happen unless the ether was entirely incompressible or else possessed no weight.

"If the ether is the *cause* of gravitation, however, it is placed outside the category of ordinary matter, and it may thus have no weight, although still having inertia—a thing impossible for ordinary matter where the weight is always exactly proportional to inertia.

"Ether, then, is not matter, but something on which many of the properties of matter depend.

"It is curious to note that Newton conceived of a theory of gravitation based on the ether, which he supposed to be more rare around ordinary matter than in free space. But the above considerations would cause the rejection of such a theory. We have absolutely no adequate theory of gravitation as produced by the ether.

"To explain magnetism, physicists usually look to some rotation in the ether. The magnetic rotation of the plane of polarization of light, together with the fact of the mere rotation of ordinary matter, as exemplified by the earth's magnetism,

both point to rotation in the ether as the cause of magnetism. A smoke ring gives, to some extent, the modern idea of a magnetic line of force. It is a vortex filament in the ether.

"Electrostatic action is more difficult to explain, and we have hardly got further than the vague idea that it is due to some sort of elastic yielding in the ether.

"Light and radiation in general are explained when we understand clearly magnetic and electrostatic actions, as the two are linked together with certainty by Maxwell's theory.

"Where is the genius who will give us an ether that will reconcile all these phenomena with one another and show that they all come from the properties of one simple fluid filling all space, the life blood of the universe—the ether?"

EXTRACTS FROM THE ENGINEERING PRESS.

AN EXISTING NEWCOMEN STEAM ENGINE.—"The steam engine has long ago attained the dignity of having a history, and, indeed, an ancient history. It is to be found in museums and collections, and already many controversies have been waged over most points in its early construction. Attempts have been made, by aid of engravings and drawings, to reconstruct some of the earlier examples, so as to give the present generation a vivid idea of the triumphs of some of the great mechanical minds long passed away. Valuable as these full-sized models are, they, nevertheless, lack actuality, and there is always a doubt in the mind of the spectator of their literal accuracy. Far better it is when an actual example can be secured, and preserved for posterity. At the present moment there is a specimen of an engine built by Newcomen, of Dartmouth, in 1705, rusting away in the open air for want of a friendly hand being put forth for its preservation. It was brought to our notice by Mr. Bryan Donkin, to whom its existence was disclosed by Mr. Samuel Fletcher, of Ashton-under-Lyne, and we have pleasure in presenting our readers with an engraving showing its condition a year ago (since then the beam has fallen over).

"For years the engine was looked upon as one of James Watt's first productions, but recent inquiries leave no doubt that it is a steam motor of the Newcomen pumping type, single-acting. Nothing is known at all trustworthy as to its history. There are a few old residents in the neighborhood who remember its being occasionally, though not regularly, worked some 60 or 70 years ago (1834) for pumping a mine, about which time it seems to have been allowed to fall into disuse. The date of its erection in Fairbottom Valley, halfway between Ashton-under-Lyne and Oldham, is uncertain, but it was prob-

ably towards the end of last century. It is still on the original site. The engine consists of a solid masonry pillar, 14 ft. 6 in. by 7 ft. 3 in. at the bottom, carrying the beam, which is made of oak, 12 in. by 14 in., braced together with iron, and has segmental ends with the balance-weight at one extremity and the

piston at the other. The beam, about 20 ft. long, rocks on two trunnions resting on the central masonry pillar, and the piston and pump rods are attached to it by chains. The cylinder, of cast iron, is about 27 3/8 in. in diameter and about 6 ft. stroke, the steam entering only at the bottom. It is cast in one piece, 8 ft. 9 in. from flange to flange, and about 1¼ in. thick. As

there was no separate condenser, condensation was effected by injecting water into the cylinder by a motion from the beam. It is impossible to say whether there were any rings round the piston, as it has not been taken apart, but probably there were none. A method often employed for keeping the joint of the piston good was to place horse-dung on the top, but other materials that retained moisture, such as turf or tow, were also used. The valve gear was off a few years ago, and the pieces were lying about, but they probably could be collected. The wrought-iron boiler, of the wagon type, is in a very bad condition; it is believed to be of a more recent date than the engine, and that the original was a haystack generator.

"The width of the boiler is 6 ft. 3 in. at the widest part, and 5 ft. 7 in. at the narrowest, the height being 7 ft. There is a steam dome 18 in. in diameter by 14 in. deep, with an 8-in. steam pipe leading vertically out of it. There are five plates in the circumference of the boiler, and 12 rings of plates in its length, the average size of plate being 19 in. by 3 ft. 6 in. The present thickness of the plates varies from 5-16 in. to zero. The pitch of the rivets is 1½ in. to 2 in.

"It appears probable that this is the oldest engine in existence, but it is in a most dilapidated state. Having been so long exposed uncovered to all weathers, the beam has nearly fallen on its side, and the boiler is worn away till it is no thicker than paper in parts, with many holes. The grievous condition of neglect and disrepair into which the engine has fallen is an object of much concern to the people in the neighborhood, who would gladly co-operate in efforts to save it from rot, rust, and total destruction. The engine is the property of the trustees of the late Earl of Stamford and Warrington.

"Any suggestion for the safe preservation of this interesting old relic will be gladly received by Mr. S. Fletcher or Mr. Bryan Donkin. These gentlemen are anxious to find a home for an object of such importance to the history of the steam engine. The above dimensions were taken personally by them during a visit to the spot about two months ago." *Engineering*, Oct. 5, 1894.

REMOVAL OF ROCK 40 FT. BELOW SURFACE OF WATER, NORTH RIVER, N. Y.—The work, of which this is a description, consist-

ed in the removal of about 2,000 cu. yds. of rock in the vicinity of Pier No. 14 (new), N. R., by the Department of Docks, City of New York.

This pier having been intended to be used for railroad purposes, the mud had been dredged to the usual depth of 25 ft. below mean low water in the slips north and south of the pier. After the pier had been completed, however, it was leased to the new American Line Steamship Company, in whose fleet are the steamships *Paris* and *New York*, and these ships drawing a maximum of 29 ft., it became necessary to make a greater depth of water along each side of the pier, the pier being also widened by the addition of 50 ft. along the entire length on the south side.

The American Line officials requested that the depth be made 35 ft. below mean low water.

As the mean rise and fall of the tide at the location in question is about 5 ft., the operation of making a grade of 35 ft. below mean low water necessitated the use of appliances that would operate and do this work in 40 ft. of water, and also accommodate themselves to the rise and fall of the tide while in operation.

The first intention as regards part of this work was to have it done by contract, and the reef south of the outer end of the pier being the one discovered first, was let, after asking for prices, to E. R. Lowe, a submarine contractor and wrecker, at a lump-sum price which amounted to about $25 per cubic yard of rock (measured in place). Work was commenced under this contract on July 25th, 1892.

Dock Department Plant.—When it became evident that the work of the removal of the reefs around Pier No. 14 (new) could not be finished by the contractor who had taken the work on one reef, the Department took the matter in hand and constructed the drill float for further operations, it having been decided to remove the reef on the north side of and near the outer end of the pier by Dock Department labor. A single-drill float had previously been used in the removal of rock to a grade of 14 ft. below mean low water on the East River. The governing idea in the construction of the large four-drill float was to use as much as possible the class of material which,

when it should be taken apart, could be used again in the bulk-head-wall construction. With this end in view, 12x12 in. spruce timber was used in the construction of the float itself. This timber was found to be exceedingly buoyant, and from actual trial the buoyancy of 1 cu. ft. was found to be about 33 lbs. After the operations of removing the rock were completed and this drill float was taken apart, the timber was not found to be at all water-logged, although it had been continually immersed in water for more than one year. The dimensions of the drill float were about 22x33½ ft., deck measurement, and 6 ft. in depth; the whole apparatus being practically floated on the two bottom courses of timber. Four drills were located on the float, operating through well-holes, each of the drills being capable of drilling a hole 12 ft. in depth without changing the drill or the drill-bar. The drills were raised and lowered in ways by two men operating a hand-winch. Two Ingersoll and two Rand drills were used, the drills being fastened to a 6-in. cast-iron column by means of the standard mining attachments, with only a few additions to enable the drill to be kept in a vertical position without turning. In drilling a hole the drills were fed by the hand-feed until the feed was run out, when the winches were called into requisition, the drills lowered, the hand-feed raised; then operations continued as before.

It was thus possible with this machine to drill the hole to the required depth without change in the drill or drill-bar, unless for other reasons than for the deepening of the holes. In order to hold this drill float steady against wave action, and also against tidal rise and fall, four anchors were used, which consisted of ordinary pile-driver hammers, weighing about 3,000 lbs. each. The drill float was accompanied by the standard Dock Department 12-ton derrick, containing two 40 H. P. boilers, and having a single mast with two booms. In locating the drill float, the derrick lifted the four pile-driver hammers, the hammers being rigged in couplets, two for each end of the float. After the hammers were clear of the bottom, the derrick and float, alongside, were floated into the desired position over the reef, and the hammers were let go and cast free from the booms of the derrick. Other lines from these hammers, or anchors, which ran over the pulleys at the corners of the drill

float, were then made fast to the hand-winches, and the whole drill float hove down by means of these winches, until the deck of the float stood about 1 ft. or 18 ins. above the surface of the water. Connections now being made from the boilers on the derrick to the steam rock-drills, the operation of drilling could commence from what had become a fairly stable structure. Where these operations were conducted, and during the period of time which they covered, there was considerable high wind and a large amount of ice, the waves oftentimes rising to a height of over 3 ft. along the side of the pier, and washing over the deck of the float. At one period, about the latter end of December, this drill float operated while surrounded entirely by ice over 6 ins. in thickness.

The nature of the rock in all these reefs was about the same, consisting of gneiss and mica schist, seamed with quite extensive veins of quartz. This made both the drilling and the blasting difficult, as the soft mica rock in some places was difficult to remove by surface blasting, even when only a small height was to be knocked down.

The holes drilled by the Department in all the reefs for the first series were spaced 6 ft. apart in northerly and southerly direction and 5 ft. apart easterly and westerly. The holes being drilled in a vertical direction, the result of the blasting seemed to be to stack the broken stones against each other, and not to loosen and throw up the mass. Divers described this bottom as being oftentimes like a pile of gravestones, one stone lying against another.

The work here described was done under the personal direction of the writer, as Assistant Engineer of the Department of Docks, of which G. S. Greene, Jr., M. Am. Soc. C. E., has been for a long period Engineer-in-Chief.

The cost of the work, divided into the several reefs, is as follows:

Reef North of Outer End–

Labor	$16,949 59
Material	3,395 42
Dredging	9,731 25
Towage	548 73 ,

Reef South of Outer End—

Labor	6,974 30
Material	1,816 84
Dredging	6,662 50
Towage	274 36
E. R. Lowe paid on account	3,798 67

Reef South of Inner End—

Labor	13,217 16
Material	2,526 24
Dredging	5,752 08
Towage	548 73
Total	$72,195 87

The cost of building the two drilling floats is as follows:

Labor	$946 18
Material	4,101 50

The calculated amount of rock removed is as follows:

Reef north of outer end	766 cu. yds.
Reef south of outer end	357 "
Reef south of inner end	407 "
Making a total of	1,530 cu. yds.

of solid rock, measured in place.

Besides this amount of solid rock, there was removed about 450 cu. yds. of rip-rap, thus making the total 1,980 cu. yds of rock removed.

The amount of Rock removed, measured in the scow, is as follows:

Reef north of outer end, by dredge	1,285 cu. yds.
" " " by divers	150 "
Reef south of outer end, by dredge	843 "
" " " by divers	118 "
Reef south of inner end, by dredge	2,677 "
" " " by divers	150 "
Making a total of rock removed and measured in the scow	5,223 cu. yds.

JOHN A. BENSEL, '84,
Trans. Am. Soc. Civil Engineers. Sept., 1894.

ELECTRICITY FOR MINING PLANTS.—The cost of installing an electical power-transmission plant in regions remote from railways, and the natural disinclination of mine managers to try experiments, have been important causes in delaying the application of electricity to mining and milling purposes. Another reason that explains the reluctance of mining companies, who sometimes undertake chimerical metallurgical ventures with surprising willingness, to introduce electrical apparatus, is the widespread ignorance of electrical matters on the part of practical miners. It seems to be hardly appreciated yet that the operation of an electrical motor under given conditions can be as easily predicted as the operation of an engine or boiler.

The thought of applying electric motors in mining operations, unfortunately, seems always to suggest electric drills, subterranean trolley roads and hoisting plants, all of which involve peculiar conditions of insulation to prevent danger from fire or injury to men by bare wires, and also other requirements not found in surface plants. The field wherein electricity is an unrivalled means of reducing the cost of mining work is not in its underground applications, where many details of construction have still to be determined by experience, but where it may be used for reducing the primary cost of a horse-power delivered at the main shaft of a mill or the drum of a hoisting engine.

If by electricity we can secure cheap motive power as the prime mover, we may still use miles of compressed air pipes, innumerable air drills, winches, and without doing violence to the prejudices of the miners, still effect a large saving in operating expenses. Having materially reduced the first cost of producing the total horse-power required, the inefficient manner in which a part may be distributed through the mine or mill does not make an item of so great importance in the expense account.

To illustrate the value that electricity may have as a factor in mining work, let us take a case under conditions that sometimes prevail, and consider a 500 horse-power mine plant located in a remote district and dependent upon wood for fuel. As the surrounding forest is destroyed for timber and fuel, the cost per horse-power will steadily become greater. If the con-

sumption of wood continues the expense for power alone will at last equal the value of the product of the mine, and its profitable working must cease.

The rapid destruction of the forest may be roughly calculated as follows: Assuming an evaporation of 8 pounds of water per pound of coal (equal to 2.5 pounds of wood) and that the engines require 25 pounds of water per horse-power per hour, we find about 7,600 cords of wood will be required annually for fuel alone. We may also assume that the large timbers are reserved for mining purposes and amount to say one-quarter of the wood cut. The total annual destruction of the forest will thus exceed 10,100 cords for a plant using only 500 horse-power. If 60 cords can be cut from an acre, we will have to cut down 167 acres, or .26 square miles, per year to supply the requirements of the plant. At the end of ten years there will have been consumed an area one mile wide and 26 miles long. If the country were uniformly wooded, and no other destructive agent had removed the wood, we should have cut the forest equally in all directions until the nearest standing timber would be nearly a mile from the boiler. These conditions, however, are too nearly ideal, for other causes, such as fires and the demand of neighboring mines, are also always active in removing the forest, so, doubtless, long before the period mentioned the visible supply of fuel would consist of a remote tract of timber land, and, notwithstanding careful contracting, the cost of fuel would increase rapidly year after year. If wood cost $4 per cord at the mine, there would be an annual expense of $31,400 for a 500 horse-power plant. Adding to this the cost of repairs, attendants, handling wood, etc., the actual expenditure for power would amount to say $37,500, or $75 per horse-power per year.

There are two methods by which the working life of a mine surrounded by such conditions may be materially prolonged. One is the construction of a railway to bring fuel more cheaply to the boilers, and the other is the utilization of the power of a distant waterfall by electrical transmission. As the ultimate fate of a boiler plant depending upon a receding forest for fuel has been made evident, let us determine how far we may be justified in transmitting the power to the mine. As a basis for calculation, take $4 per cord as the maximum price that can be

paid for fuel and allow a reasonable profit on the product. To make the calculations approach possibilities of actual practice, suppose an electro-motive force of 2,000 or 3,000 volts is to be used on the pole line, and the simplest electrical appliances are to be employed.

Since the cost of the generating and receiving plants will be substantially the same whether they are one or fifty miles apart, the problem becomes a determination of the possible distance over which it will pay to transmit the power.

Remembering that the weight of copper required for conductors varies with the square of the distance for a given electro-motive force and also inversely as the square of the electro-motive force for different voltages, if we determine the number of dollars to be expended, a complete solution can be obtained for any electro-motive force desired after knowing the total cost of copper per pound on the line.

Let us then put Fs = first cost of steam plant.

Ps = percentage covering interest, depreciation and repairs.

Cs = wages, oil, waste, taxes, insurance, etc.

A = cost of fuel per pound of steam.

N = number of horse-power hours per year the plant is operated.

S = number pounds of steam per horse-power hour.

The annual cost of operating will then evidently be Ps Fs + A N S + Cs.

Also, let Fe = first cost of electric plant.

Pe = percentage covering interest, depreciation and repairs.

Fh = first cost of hydraulic plant required for driving generators.

Ph = Percentage covering depreciation, interest and repairs.

Fi = first cost of copper conductors between generating and receiving station.

Pi = Percentage covering depreciation, etc.

Ce = constant expenses electric plant.

Ch = constant expenses hydraulic plant.

Ci = constant expenses pole line.

Old and New Methods with the Indicator.—Some years back indicating an engine was pretty much a two-days' job.

It was looked upon as good time if the engine was not stopped over half a day and the result reported within forty-eight hours. Let us compare this with later methods. For rapid work the following would probably be best suited: first, an indicator with attached reducing-wheel; second, a three-way cock, with elbow and three or four short pieces of five-ply half-inch steam hose, with elbow and union piece attached; and last, the drilled standard. A monkey-wrench, a brace, a $\frac{7}{16}$ drill and a half-inch hob tap will be all the tools called for. The cross-head is first drilled and tapped and the standard screwed in. The plugs are then removed and the three-way cock screwed into rod end of cylinder. That piece of steam hose is selected which comes nearest the cylinder length, and its elbow screwed into head end of cylinder and its union connection made tight into the three-way cock. The proper spring is put in indicator and the proper bushing put on reducing-wheel. The cord is run forward to hole in standard, which comes level with bottom of reducing-wheel and the card is taken. If the indicator and reducing-wheel are set up for engine before starting, there is no reason why the job should take over fifteen minutes.

If there is no planimeter available, calculating the card is about like it used to be, except that to any one acquainted with the use of logarithms, the work is greatly expedited by their use. With the ordinary planimeter the mean effective pressure can be obtained without much figuring. Other planimeters will give mean effective pressure as if card were taken with a forty-pound spring, and a correction is applied to reduce reading to that of the spring used. After obtaining the mean effective pressure, the horse-power is only a matter of multiplication and long division.

The writer has lately patented a planimeter which will read mean effective pressure and horse-power direct from the card without calculation of any kind. Provided with the attachments mentioned and this direct-reading planimeter, the writer has frequently attached, indicated and reported the horse-power of an engine inside of fifteen minutes; and there is no reason why any one familiar with the work and instrument should take a great deal longer.

It would at first sight appear that the steam hose connec-

tions would be objectionable and cause inaccurate cards. It will, however, be noted that the hose is the same bore and practically the same length as the half-inch pipe usually employed when one indicator is used. By selecting the shortest length of hose which will reach the union, there should not be be over two or three inches more hose than there would be steam pipe. In some instances, on account of the rectangular piping necessitated around the throttle, there is really less hose than there would be pipe. For some years the writer has used this method and has never noticed any difference between the cards taken through the hose and those taken through pipe. The only trouble met with has been that with new hose the steam carries a black gum over to the piston and fouls it badly.

In connection with attaching the indicator there occurs an effect on the card which may have passed unnoticed, or, if noticed, unexplained. Sometimes cards have hooks or beaks at the end of compression. This is due to the engine-piston closing the indicator-ports at each end of the stroke, and the only remedy is to cape out well from holes into counter-boring. It would seem pretty hard to explain the hooks by valve-action, but in one instance a party had it so thoroughly explained to his own satisfaction that only by caping out into the counter-boring before him was it possible to prove that this was the cause. - *Edward J. Willis, M. E., in Machinery, Dec., 1894.*

RECENT RESEARCHES IN THE INFRA-RED SPECTRUM.—"Nature," in its issue of November 1, 1894, describes the latest discoveries of S. P. Langley on this subject. He has lately perfected and set up at Washington an apparatus in which the use of the bolometer instead of a thermo-pile gives extreme accuracy, while an automatic device for recording the spectral lines makes possible, in one day, more results than were previously obtained in two years of labor. He describes his apparatus as follows:

"The Foucault siderostat, perhaps the most powerful instrument of the kind existing, was originally made by Sir Howard Grubb of Dublin, from my indications; but its dispositions have since been considerably modified. A beam from its twenty-inch mirror is conveyed through the slit of a horizontal

collimating telescope, having a rock salt objective of nearly seventeen centimetres aperture, and of ten metres focal length, to the prism or grating. The prism is of rock-salt of corresponding dimensions, worked (by Brashear) with the precision of, and presenting all the external appearance of one of flint glass. It is mounted on a massive spectro-bolometer (as the instrument which supports the prism or grating used in producing the spectrum is called). This instrument includes a large azimuth circle, over the centre of which the prism is placed, and it also carries the bolometer, which registers the spectral heat. The focal length of the image-forming lens, or mirror, is in this instrument much greater than in the first one used, and all parts of the apparatus are correspondingly increased in size and stability. The most important and novel feature is, however, the mechanical connection of the large azimuthal circle carrying the prism, with a distant photographic plate, susceptible of vertical motion, and which latter takes the place of the scale formerly in front of the remote galvanometer, both circle and plate being moved by the same clockwork, which is of such steadiness and precision as to make the two movements as far as possible perfectly synchronous."

Such is the refinement of this apparatus that the bolometer will detect changes of temperature which are less than $\frac{1}{10000000}$ of a degree centigrade, while it is possible to distinguish lines separated by three seconds or less of arc. Supposing the part of the spectrum under observation to cover 2° or 7200″, it is seen that 2000 lines, if they exist, can be mapped. But these lines do exist, and many of them have been recorded.

Refined as these experiments are, it may be said that research in this direction has only begun, as no attempt has been made to interpret the lines; but the importance of the matter may be realized when we consider that this part of the spectrum embraces three-quarters of the whole energy of the sun.

CONCENTRATION AND DISTILLATION OF H_2O_2.— In the "Berichte der deutschen chemeschen Gesellschaft," Richard Wolffenstein describes some recent experiments with peroxide of hydrogen. He found that an aqueous solution of H_2O_2, if sufficiently pure, can easily be concentrated by heat-

ing in a partial vacuum. A three-per-cent. solution of H_2O_2 can be concentrated to 45% without material loss. With higher concentration, the volatility of the substance increases rapidly, until, at 68 millimetres pressure and 84° to 85° C., almost perfectly anhydrous H_2O_2 is distilled over. This is free from all impurity. It is a clear, colorless, syrupy fluid, and evaporates in the air.

In contact with the skin, it produces a prickling sensation and white spots, which disappear in a few hours.

In endeavoring to liquefy the two hydrates, $H_2O_2 + H_2O$ and $H_2O_2 + 2H_2O$, he found that neither was affected by a temperature of — 20° C., and they could only be frozen by a mixture of ether and solid carbonic acid.

INSTITUTE NOTES.

THE INSTITUTE CATALOGUE for 1895–6 will contain the following notices:

"When applicants for admission reside a great distance from the Institute, arrangements will be made for their examination at localities more readily accessible to them."

"The requirements for admission in 1895 will not include French unless applicant desires to pursue the study of Spanish in the regular course. In such cases the requirements in French will be as stated in this Catalogue."

THE MIDWINTER MEETING of the Alumni Association of the Stevens Institute of Technology will be held in the Lecture Room, at Hoboken, N. J., on Wednesday evening, February 20, 1895, at eight o'clock. It will partake mainly of an informal social nature, and the usual collation provided by the Association will be served. The Executive Committee expects to provide other social attractions as a further inducement for most of the members to be present.

PRESIDENT MORTON has presented the Electrical Laboratory with a 300-incandescent-light dynamo (a 150-ampere, 110-volt machine), such as the manufacturers sell at $1,000. Dr. Geyer has taken evident pleasure in locating this valuable acquisition to his laboratory.

PROF. A. M. MAYER, at the Regular Meeting of the Academy of Sciences, on Nov. 5, in Hamilton Hall, Columbia College, read a paper "On the Production of Beats and Beat-Tones by Two Vibratory Bodies whose Frequencies of Vibration are so Great as to Surpass the Limit of Audibility."

At the meeting of the Academy on Jan. 7, Prof. Mayer presented a paper "On Chladni's figures formed on vibrating plates strewn with sand; with experiments showing the method of obtaining these figures and the exhibition of the figures in sand transferred to paper by a process invented by Prof. Mayer; also, the comparison of the real figures with those given by the Physico-Mathematical investigations of Lord Rayleigh, and with those given in text-books on Physics."

THE PAPER PRESENTED BY PROFESSOR JACOBUS at the December Meeting of the American Society of Mechanical Engineers, entitled "Results of Measurements to Test the Accuracy of Small Throttling Calorimeters," has been extensively copied by the engineering press, both American and foreign, and has attracted very general attention.

AT THE SECOND GENERAL MEETING of the Society of Naval Architects and Marine Engineers, held in the auditorium of the American Society of Mechanical Engineers, No. 12 West Thirty-first street, New York, on November 15 and 16, Professors Denton and Jacobus and A. W. Stahl, '76; G. C. Henning, '76, and H. L. Gantt, '84, were in attendance. Mr. Stahl read a paper on Hydraulic Power for War Ships. Professor Jacobus discussed the paper on "A Dynamic Steam Engine Indicator Tester" of Professors Peabody and Miller, of Massachusetts Institute of Technology. Mr. Gantt joined in the discussion of the paper on "Present Status of Face-Hardened Armor," presented by Capt. W. T. Sampson, Chief of Ordnance, U. S. N.

PROFESSORS DENTON AND JACOBUS have conducted an exhaustive test of Stratton Separators, with a view to determine their efficiency with varying percentages of moisture.

PROFESSOR JACOBUS made a trip in December to Southampton in the American Line steamship *New York*, to test for Prof. Denton the comparative value of two lubricants, one of which was used on the engines during the outward voyage and the other during the return trip.

AMONG the members and guests of the American Society of Mechanical Engineers who registered at the Annual Meeting of the Society, Dec., 1894, were the following members of Stevens Alumni Association:

W. S. Ackerman,
H. A. Bang,
Geo. M. Bond,
W. H. Bristol,
A. E. Bruen,
G. E. Bruen,
Gordon Campbell,
L. Carter,
James M. Cremer,
Orton G. Dale,
W. W. Dashiell,
G. D. Dinkel,
A. F. du Faur,
E. D. Estrada,
E. H. Foster,
H. L. Gantt,
C. A. Greenidge,
G. C. Henning,
F. E. Idell,
D. S. Jacobus,
M. C. Jenkins,
F. C. Jones,
Wm. Kent,
C. V. Kerr,
A. Lenssen,
J. W. Lieb, Jr.,
Wm. O. Ludlow,
W. L. Lyall,
H. C. Meyer, Jr.,
A. B. Moore,
H. de B. Parsons,
W. E. Quimby,
J. M. Rusby,
J. E. Sague,
Geo. M. Sinclair,
Albert Spies,
H. W. Smith,
E. A. Stevens,
F. N. Taff,
G. L. Todd,
K. Torrance,
A. P. Trautwein,
Fred'k N. Vreeland,
J. B. Webb,
H. C. White,
Maunsel White,
A. R. Williams,
De Volson Wood,
A. R. Wolff,
W. B. Yereance.

To G. W. COLLES AND E. B. GALLAGHER, '94, has been awarded the prize offered by the *Engineering News* for the best thesis written by graduates of any scientific institution in the United States or Canada, and submitted for competition.

The title of the successful thesis is Test of an Electric Railway Power Station at West Haven, Conn.

STEVENS ENGINEERING SOCIETY.

The first meeting of the year was held on Thursday, Oct. 25. Mr. B. C. Ball, '95, read a paper on "Steam-Engine Governors," in which he described the various forms of fly-wheel governors now in use, and explained their theory and mode of adjustment.

Mr. Greenidge, '95, spoke on the manufacture of paper, describing the process employed in a mill in which scrap paper is used as stock.

A new feature for these meetings was then introduced, namely, a review by Mr. Ganz, '95, of the current technical periodicals. He called attention to several interesting articles, among them "Power Transmission by Compressed Air," and "Theory and Practice of the Friction Clutch."

On Nov. 9 the second meeting was held, when Mr. Corbett, '95, read a paper whose subject was "A Review of Water as a Motive Power." The paper was illustrated by drawings, and covered the history of the utilization of water-power from the primitive water-wheel to the modern turbine. Mr. Ganz again reviewed the technical papers, noting especially articles on "The Breaking of Fly-Wheels," "Windmills in Electric Lighting," and "Welding by Electricity."

At the meeting of Friday, Nov. 23, Mr. Paulding, '95, related an experience in testing a simple non-condensing engine. He showed on the screen cards taken when the engine was consuming 80 lbs. of steam per hour per H. P., and pointed out the peculiarities of the card which indicated faulty adjustment of the valves and governor. After these defects had been remedied the water-consumption was reduced to 60 lbs. per hour per H. P.

Mr. Walker, '95, reviewed the mechanical journals, describing the electrolytic extraction of aluminium, and mentioning some of the uses to which the metal is put. He also spoke on the disposal of sewage and garbage, and explained several processes in use in Europe.

Mr. Boucher, '96, reviewed the electrical journals. He explained the new conduit electric railway which is being constructed in New York, in which the conductors are of channel iron, supported by soapstone insulators. He next described the Sperry electric brake. In this device the ordinary brake-shoe on the tread of the wheel is replaced by a disc which presses on the inner face of the wheel. The pressure is caused by magnetic attraction between the disc, which is magnetized by a coil imbedded in it, and the car-wheel. The current for the brake is supplied by the motors, which are temporarily turned into dynamos, and thus the reaction of the armature helps to stop the car.

At the meeting of Dec. 6 Mr. Rae, '96, read a paper on Naphtha Engines and Launches, giving a very clear and complete description of the entire plant--engine, boiler, and condensing device.

Mr. Schmidt, '95, reviewed the mechanical journals, abstracting the report of the committee of engineers to determine the maximum practical length of span of the proposed suspension bridge over the Hudson River.

Mr. Vreeland, '95, reviewed the electrical journals. He called attention to a new process of making electric-light carbons of carborandum, and described an automatic engine-stop, which is designed to stop an engine when a button is pressed in any part of a factory, or when the engine starts to run away.

The first meeting of the Engineering Society in 1895 was held Jan. 11 when a large number of members and under-classmen listened to a paper by Prof. Anderson on the making of Lantern Slides. He explained the whole process very clearly, and described the necessary apparatus, including several ingenious devices of his own design.

Mr. Allan, '95, reviewed the mechanical journals, calling special attention to an article on dynamometers, and Mr. Boucher, '96, reviewed the electrical periodicals, describing, among other things, the process of manufacture of incandescent lamps, and the Budapest electric railway.

MUSICAL CLUBS.

Concerts by the Glee, Banjo, and Mandolin Clubs have been arranged for in Hoboken, on January 15; Jersey City, January 22; Bergen Point, January 29, and Montclair, February 4.

CHESS CLUB.

A meeting of the Chess Club was held to elect officers for the ensuing year. The following men were elected: President, H. H. Maxfield, '95; Vice-President, G. Rae, '96; Secretary, E. F. Burnet, '96; Treasurer, Guy Hopkins, '95; members of Executive Committee: M. J. Weichert, '96; R. E. Hall, '95; W. C. Morris, '96. A committee is arranging for the annual tournament.

THE SOUTHERN CLUB.

At the last meeting of the Southern Club the following officers were elected: J. B. Hamilton, '95, President; E. Campbell, '96, Vice-president; J. P. Kennedy, '96, Secretary and Treasurer.

FOOTBALL.

The annual dinner of the football team of 1894 was held on Wednesday evening, Oct. 24. The team performed its last act as an organization by electing Mr. Jennings, '96, Captain for 1895.

TENNIS.

At a recent meeting of the Tennis Club a prize was awarded to each of the class champions, namely, Messrs. Walker, '95; Summerhayes, '96; Millard, '97, and Scott, '98. The tournament for the college championship, which was deferred owing to unfavorable weather, may be held in the spring.

INSTITUTE PERSONALS.

It is our endeavor to notice under this heading such items of news affecting graduates of the Institute as may interest their classmates and friends among the Alumni. We are indebted to a few members for regular or frequent contributions of items, and wish to make it known that the co-operation of all is most desirable, and will be appreciated. MANAGING EDITOR.

'76.

GUS. C. HENNING, in *The American Machinist* of December 27, reviews a recent work in German on "Elasticity and Resistance of Materials," by Prof. C. Bach, of the Technical School at Stuttgart, and states that the results of all of Prof. Bach's experiments on flat plates prove uniformly that their resistance varies as the square of the thickness, and not as the first power.

Under the title "A Paradox in Hydraulics," Mr. Henning gives, in *The American Machinist* of January 3, a mathematical analysis of the action of an impact pump, and calls attention to the fact that under some conditions a reciprocating pump will deliver a considerable quantity of water in excess of the product of the volume of its cylinder by the number of strokes.

A. W. STAHL, who has for several years been on duty as Chief Constructor, U. S. N., at the Union Iron Works, San Francisco, has been ordered to the Washington Navy Yard, the most important post in the Department in respect to constructive engineering work.

At the November Meeting of the Society of Naval Architects and Marine Engineers he read a comprehensive paper on "Hydraulic Power for Warships," in which he explained the possibility of further extension of the application of such power, called attention to the consequent advantages, and expressed the hope that the Navy Department will authorize the adoption of a comprehensive system of hydraulic power in one of the new vessels.

This paper, with very complete illustrations, is published in the Transactions of the Society of Naval Architects and Marine Engineers, Vol. 2, 1894.

Naval Constructor Stahl finished some weeks ago the two designs proposed, one cylindrical and the other elliptical, for the turrets of the battleship *Iowa* and the cruiser *Brooklyn*.

The Bureau of Ordnance officers favored the cylindrical design, claiming it possesses greater strength, contains more room, and is cheaper; and Secretary Herbert has decided to adopt it.

'79.

JAMES KELLY, having severed his connection with the Edison Wire Works, has entered the selling department of the New York Insulated Wire Company.

'80.

GEO. M. BOND is a member of the Committee on Standard Gauges for Thickness appointed by the American Society of Mechanical Engineers.

This committee (which is composed of the following engineers: Thos. Eggleston, S. T. Wellman, Oberlin Smith, and Schuyler S. Wheeler, in addition to Mr. Bond) has corresponded during the past year with a number of American and foreign societies, with a view to securing the adoption of a uniform system, and find that the action is likely to be unanimous in favor of abolishing gauges and the adoption of a decimal system for diameters and thicknesses.

The French Government have abolished the arbitrary gauge-system absolutely, and have made the legal measurement to be the hundredth of a millimetre.

The following resolution, offered by the committee, was unanimously adopted, and the committee continued:

Resolved, That the American Society of Mechanical Engineers recommends to its members, and urges upon all persons using a gauge-system, to abandon the use of arbitrary gauges and to give the actual thicknesses and diameters in a decimal system.

J. W. LIEB, JR., who was the Technical Director of the Edison Company at Milan, Italy, for nearly twelve years, returned to this country early last year. He resumed his connection with the Edison Electric Illuminating Company of New York, and is now the Assistant General Manager.

'81.

ALBERT SPIES has written an interesting article in *Cassier's Magazine* for November, going into the details of the history of the first iron casting in America.

'82.

PIERCE BUTLER returned last fall from a trip with his wife to Europe, and has opened an office as Mechanical Engineer in the Norton Building, Louisville, Kentucky.

GEO. GIBBS has recently closed a contract with the Chicago, Milwaukee, and St. Paul R. R. for one of his interlocking signal plants to protect an electric street-car crossing at Grayland, Illinois.

ROGER H. WHITLOCK was married to Miss Effie Dean Cable on December 25, at Mackinac Island, Michigan.

'83.

L. S. RANDOLPH presented, at the December meeting of the American Society of Mechanical Engineers, a paper entitled "Strength of Railway Car Axles," and embodying some calculations made by the writer of the strains upon the axles of freight cars.

'84.

JOHN A. BENSEL, under whose direction, as Assistant Engineer of the Department of Docks of New York City, the removal of about 2,000 cubic yards of rock, in the vicinity of Pier No. 14, in 1892 and 1893, was accom-

plished, thereby securing a depth of 35 feet below mean low water, for the American Line steamships *Paris* and *New York*, read a paper at the Annual Convention in June, of the American Society of Civil Engineers, describing in detail the difficulties encountered and the methods employed in the removal of this rock as much as 40 feet below the surface of the water.

GEO. M. SINCLAIR, in "Notes on Steel Forgings," a paper presented at the December meeting of the American Society of Mechanical Engineers, concisely states some of the general principles controlling the manufacture and use of steel forgings.

ALEXANDER JAY WURTS will deliver a lecture on "Lightning Arresters" on March 15th, in the Franklin Institute course of lectures for the season of 1894–1895, at 15 South Seventh Street, Philadelphia, Pa.

'86.

C. J. FIELD presented, at the December meeting of the American Society of Mechanical Engineers, a paper on "Present and Prospective Development of Electric Tramways," in which he gave separate consideration to Road Bed, Line Construction, Underground Construction, Cars and their Equipment, Motor Equipments, Power House and Operating Expenses, and Cost of Equipment.

FRANCIS E. JACKSON has recently associated himself with Mr. J. W. Aylsworth in the manufacture of incandescent lamp filaments and other carbon specialties. Mr. Jackson has for several years had charge of the lamp-testing department of the General Electric Company's factory, at Harrison, N. J., where Mr. Aylsworth was chemist, in charge of the carbonizing department. Their factory is located at 128 Essex Avenue, Orange, N. J.

FRED. N. MORTON has left St. Albans, Vt., and is Superintendent of the Lockport Gas and Electric Light Company, of Lockport, N. Y.

'87.

JAMES H. BATES has opened an office as Consulting Mechanical and Electrical Engineer, at 126 Liberty Street, New York. His attention, ever since completing the course at Stevens, has been directed to traction problems relating largely to cable and trolley systems as applied to street-car service, and street-railway construction and equipment will be a specialty with him.

'88.

EDWARD J. WILLIS, who is General Manager of Talbott & Sons, Richmond, Va., one of the oldest and largest concerns manufacturing stationary engines and boilers in the South, has recently patented a planimeter which will give readings of mean effective pressure and of horse-power direct from the card, without requiring any calculation whatever.

'89.

ROBERT GASTEN SMITH, who is continuing his studies at Cambridge, has announced the change of his name to Robert Keating Smith, by an act of the Probate Court, Cambridge, Mass.

ROBERT E. WYANT is Superintendent of Colorado Springs Gas and Electric Company, Colorado Springs, Col.

'90.

SHIRK BOYER is connected with Humphreys & Glasgow, 64 Broadway, New York.

J. T. WESTCOTT has recently secured for his corporation, the Economical Gas Apparatus Construction Co., of Toronto, Canada, an order to build a water-gas plant for the Blackburn Corporation, England, with a capacity of 1,250,000 cubic feet per day. In connection with an extended interview on the subjects of Water-Gas *vs.* Electricity, and Combined Carburetters and Superheaters *vs.* Double Superheaters, *The Gas World*, of London, January 5, publishes a biographical sketch of Mr. Westcott, in which reference is made to Stevens as the admirable institution where he received his mechanical engineering training.

'91.

BENJAMIN W. CARLL has severed his connection with the German-American Insurance Co. and has accepted a position with James Beggs & Co., 9 Dey Street, New York city.

'92.

CARLL H. HOTOPP is Superintendent of the Tanite Company, Stroudsburgh, Pa.

W. D. WHITCOMB, who is Inspector for R. W. Hildreth & Co., notifies us that the firm has removed to 50 Broadway, New York, where all communications for him should be addressed.

'93.

FRANKLIN D. FURMAN, Instructor in Mechanical Drawing at Stevens Institute, was married on Saturday, Nov. 3, to Miss Minnie A. Thompson, at the home of the bride, at Spring Valley, N. Y.

MORS O. SLOCUM and Miss Gertrude Goodwill Glass were married on Dec. 27 at the Central Presbyterian Church, Rochester, N. Y.

GEO. L. WALL has entered the shops of the Southern R. R., at Nashville, Tenn.

'94.

H. D. LAWTON has been engaged by Euhling & Steinbart, who are developing and introducing their Pneumatic Pyrometers. He is now standardizing and testing these instruments at the Institute.

FRANK H. COYNE has presented his thesis on the Manufacture of Wood Fibre, and has received his diploma.

E. B. GALLAGHER has been appointed by the Brooklyn, Newtown, and Bowery Bay Railway Co. Engineer-in-Charge of the construction of a 12-mile trolley road, to run from Greenpoint to Bowery Bay, Long Island. It is also reported that he has organized a company and secured a charter for a trolley road at Peekskill, N. Y., for which the consent of property-owners is now being secured.

LIST OF MEMBERS OF THE ALUMNI ASSOCIATION OF STEVENS INSTITUTE.

It is contemplated to publish in the January number of each year a list of the members of the Alumni Association, together with the business address of each.

Absolute accuracy in such a list is impossible. Care has been taken to make this list as correct as practicable; and omissions and errors will be corrected in succeeding lists, if the facts are brought to our notice.

All active members have received the degree of Mechanical Engineer, excepting those whose degrees are stated in foot notes.

Degrees in addition to M. E. conferred upon members are noted after the names of the recipients. Associate members are indicated by the word "Assoc.," following the name, and preceding the date of the class with which the member was identified.

ACKERMAN, WILLIAM S., '91—Consulting Engineer, Nat. Lead Co., 1 Broadway, New York City.

ADAMS, HARRY H., '93—Consolidated Traction Co., Jersey City, N. J.

ADRIANCE, WILLIAM A., '85—Adriance, Platt & Co., Manufacturers of Agricultural Machinery, Poughkeepsie, N. Y.

AGUILERA, ANTONIO, JR., '86—With Bernally Sanchez Sugar Co., Porto Principe, Cuba.

ALDEN, JAMES S., '84—Assistant Manager, Brick Factory of L. H. Alden, Passaic, N. J.

ALDRICH, WILLIAM S., '84—Professor of Mechanical Engineering, West Virginia University, Morgantown, W. Va.

ANDERSON, LARZ W., '88—Treasurer, J. A. Fay & Egan Co., Cincinnati, O.

ANDERSON, ROBERT M., '87—Assistant Professor of Applied Mathematics, Stevens Institute of Technology.

ANDERSON, ST. GEO. M., '94—Assistant to State Chemist, 103 W. Franklin Street, Richmond, Va.

ANGELL, F. J., '94—Pennsylvania Railroad Shops, Altoona, Pa.

ANTZ, OSCAR, '78—Lake Shore Railway, Brainard Block, Cleveland, O.; also Instructor in Mechanical Engineering, The Correspondence School of Technology, Cleveland, O.

ASPINWALL, JOHN, Assoc., '81.—35th Street, cor. First Avenue, New York.

ATKINS, HAROLD B., '92—Superintendent, Pintsch Compressing Co.'s Boston Works, Boston, Mass.

ATRISTAIN, ALBERTO, '90—Draughtsman, Mexican Central R. R., Mexico City, Mexico.

ATWATER, C. G., '91 -R. M. Atwater & Sons, Glass Engineers, Ferguson Block, Pittsburg, Pa.

AYRES, BROWN,* '78--Professor of Physics, Tulane University of Louisiana, New Orleans, La.

AXFORD, WILLIAM B., '93 -W. H. Axford & Son, Heavy Building Contractors and Engineers, 310 Eighth Street, Jersey City, N. J.

BALDWIN, OSCAR, '85—Westinghouse Electric and Manufacturing Co., Pittsburg, Pa.

BANG, HENRY A., '88 -Benham & Bang, Consulting Mechanical Engineers, 1186 Broadway, New York City.

BARNES, WILLIAM O., '84- -Gregory Silk Manufacturing Co., Scranton, Pa.

BATES, JAMES H., '87 -Consulting, Contracting, Mechanical, and Electrical Engineer, 126 Liberty Street, New York City.

BAYLES, ROBERT N., '87 -81 Fulton Street, New York City.

BAYLESS, C. T., '93- -With D. L. Barnes, Consulting Engineer, 768 Rookery Building, Chicago, Ill.

BEARD, M. C., '87- Half owner Ontario Iron Works, Canandaigua, N. Y.

BEERS, WILLIAM J., '89 -Draughtsman, W. D. Forbes & Co., Engineers, Thirteenth and Hudson Streets, Hoboken, N. J.

BENNS, CHARLES P., '89 -Instructor, Providence Manual Training School, Providence, R. I.

BENSEL, JOHN A., '84 -Assistant Engineer, Department of Docks, Pier A, North River, New York City.

BEYER, RICHARD, '88 -Assistant Engineer, with T. H. McCann, Civil Engineer, Hoboken, N. J.

BIRCHARD, PLINY T., '78 Firm of P. T. Birchard & Co., Railroad Contractors, Marshalltown, Iowa.

BLAUVELT, CORNELIUS D., '86- Calume Gas Co., So. Chicago, Ill.

BOLLER, A. P., JR., '91 -Testing Department, H. R. Worthington Hydraulic Works, Brooklyn, N. Y.

BOND, GEORGE M., '89 -Manager, Gauge Department, Pratt & Whitney Co., Hartford, Conn.

BONN, HILLRIC J., '78 -Weehawken, N. J.

BONNETT, LOUIS B., '89 - Assistant to Secretary, American Society of Civil Engineers, 127 East Twenty-third Street, New York City.

BOODY, ALVIN, '93 206 Berkley Place, Brooklyn, N. Y.

BOYER, SHIRK, '90 Humphreys & Glasgow, Contracting and Consulting Gas Engineers, 64 Broadway, New York City.

BRAINARD, ALLEN W., '84- Manufacturers' Agent, 41 Dey Street, New York.

BRAINE, BANCROFT G., '93- With Thos. E. Brown, Consulting Engineer, Otis Elevator Co., 114 Nassau Street, New York City.

* Received Degree of Doctor of Philosophy.

BREWER, SAMUEL B., '76, Draughtsman, 30 North Pearl Street, Albany, N. Y.

BRINCKERHOFF, HENRY M., '90—Electrical Engineer, the Metropolitan West Side Elevated R. R. Co., 1313 Monadnock Block, Chicago, Ill.

BRISTOL, B. B., '93—Secretary, The Bristol Co., Waterbury, Conn.

BRISTOL, WILLIAM H., '84—Assistant Professor of Mathematics, Stevens Institute of Technology. President of the Bristol Co., Waterbury, Conn.

BROADMEADOW, WILLIAM J., '85 -With W. P. Stevenson, 115 Broadway, New York City, and Superintendent, Sea Shore Electric Railway Co., Asbury Park, N. J.

BROOKFIELD, A. B., '93 With Baker & Co., Newark, N. J.

BROOKS, MORGAN, '83 -Secretary and Treasurer, Electric Engineering and Supply Co., 413 Jackson Street, St. Paul, Minn.

BROWN, WILBUR V.,* '80 -Assistant Professor of Mathematics and Assistant Director of Observatory, De Pauw University, Greencastle, Ind.

BRÜCK, HENRY T., '78- Master of Machinery, Cumberland and Pennsylvania Railroad, Mt. Savage, Md.

BRUEN, ALBERT E., '93--256 Cumberland Street, Brooklyn, N. Y.

BUFFETT, E. P., JR., '94 -With *American Manufacturer and Iron Worker*, Pittsburg, Pa.

BURCHARD, ANSON W., '85- Superintendent of Construction, J. M. Ives Company, Danbury, Conn.

BURHORN, EDWIN, '85- -Warren & Burhorn, Agents, Stearns Manufacturing Co., 136 Liberty Street, New York City.

BURKE, E. J., '94 -Alexandria, Va.

BUSH, PRESCOTT, '84 - Superintendent of Motive Power, Pennsylvania Lines west of Pittsburg, Columbus, O.

BUTLER, PIERCE, '82 -Mechanical Engineer, Norton Building, Louisville, Ky.

BUVINGER, WILLIAM S., '91 -Chief Draughtsman, Thos. Carlin's Engine Works, Pittsburg, Pa.

CALISCH, JULIUS, '87--Railway Department, Pennsylvania General Electric Co., Pittsburg Branch, 425 Wood Street, Pittsburg, Pa.

CAMERON, BARTON H., '94- Norfolk & Western R. R. Shops, Radford, Va.

CAMPBELL, GORDON, '88- -Purchasing Agent, Consolidated Traction Co., Jersey City, N. J.

CAMPBELL, NORMAN ST. G., '88 Firm of W. D. Forbes & Co., 1300 Hudson Street, Hoboken, N. J.

CARLL, BENJAMIN W., '91 -James Beggs & Co., 9 Dey Street, New York City.

* Received Degree of Doctor of Philosophy.

CARLTON, WILLIAM N., '90 -Mechanical Engineer, 109 White Building, Buffalo, N. Y.

CARROLL, LAFAYETTE D., '84--Mechanical and Electrical Engineer, 10 Union Street, New Orleans, La.

CHANDLER, R. E., '93—Professor of Mechanical Engineering, Agricultural College, Bozeman, Mont.

CHESTER, WILLIAM S., '86--Electrician, C. & C. Electric Motor Co., 143 Liberty Street, New York City.

CLERK, WILLIAM T., '85 -Architect, Hopkin's Block, 1003½ State Street, Santa Barbara, Cal.

COFFEY, BARTON H., '85 -Mechanical Engineer, The International Contracting Co., Post Building, 12-18 Exchange Place, New York City.

COHEN, F. W. '92--Pennsylvania Steel Co., Steelton, Pa.

COLEMAN, H. D., Jr., '94—With H. Dudley Coleman & Co., Manfacturers of Plantation Machinery, New Orleans, La.

COLLES, GEO. W., Jr., '94 -Pennsylvania R. R. Shops, Hoboken, N. J.

COLLINS, CHARLES RUSSELL, '86 -Inspector of Manufacturing, United Gas Improvement Co., Philadelphia, Pa.

CONNET, F. N., '90- Chief Draughtsman, Builders' Iron Foundry, Providence, R. I.

COOK, EDWIN J., '86—Constructing Engineer, Cleveland General Electric Co., Cleveland, O.

COOK, H. B., '93 -B. F. Sturtevant Co., 135 N. 3d Street, Philadelphia, Pa.

COOKE, FREDERICK W., '82- Vice-President, Cooke Locomotive and Machine Co., Paterson, N. J.

COOKE, JOHN S., '79 -President and General Manager, Cooke Locomotive and Machine Co., Paterson, N. J.

CORBETT, L. B., '92 Secretary, South Branch Manufacturing Co., Manufacturers of Chemicals from Wood, Galeton, Potter Co., Pa.

CORBIN, D., '94 206 McDonough Street, Brooklyn, N. Y.

CORWIN, WILLIAM S., '85 -253 Mt. Pleasant Avenue, Newark, N. J.

COSTER, MAURICE L., '77- Westinghouse Electric and Manufacturing Co., Pittsburg, Pa.

COTTIER, JOSEPH, '94 East River Gas Co., Ravenswood, N. Y.

COX, JAMES M., '94 Assistant Superintendent of Terminal Station, Philadelphia and Reading Railroad.

COX, JOHN LYMAN, '87--Assistant Forgemaster, Midvale Steele Co., Nicetown, Pa.

COYNE, F. H., '94 10 Arlington Avenue, East Orange, N. J.

CREMER, JAMES M., '76 -Consulting Engineer, 170 Gates Avenue, Brooklyn, N. Y.

CRISFIELD, JAMES A. P., '87 Superintendent (for United Gas Improvement Co.) Savannah Gaslight Co., Savannah, Ga.

CRONISE, ERNEST S., '81—Mechanical Engineer, 17 Broad Street, New York City.

CUNTZ, HERMANN F., '93—Chemist, Pope Manufacturing Co., Hartford, Conn.

CUNTZ, J. H., '87—325 Hudson Street, Hoboken, N. J.

CUNTZ, WILLIAM C., '92—Pennsylvania Steel Co., Steelton, Pa.

DALE, O. G., '93—Draughtsman, National Sugar Refining Co., Yonkers, N. Y.

DANZIGER, JACOB, '89—Testing Department, Bethlehem Iron Co., Bethlehem, Pa.

DARBY, JOHN, '91—Wolcott & Darby, Mechanical Engineers, 278½ Main Street, Hartford, Conn.

DASHIELL, WILLIAM W., '79—W. W. Dashiell & Co., Motive Power and Machinery Supplies, 64 Cortlandt Street, New York City.

DAVIS, JESSE A., '91—Office of Engineer of Tests, Mt. Clare Shops, Baltimore and Ohio Railroad, Baltimore, Md.

DEAR, WILLIAM Y.,'93—Salesman, Jersey City Printing Co., 37 Montgomery Street, Jersey City, N. J.

DE BONNEVILLE, ARTHUR A., JR.,'78—Salesman, The Geo. F. Blake Manfacturing Co., Manufacturers of Steam Pumps, 95 Liberty Street, New York City.

DE GRESS, F. B., '91—Crocker-Wheeler Motor Company, 430 West Fourteenth Street, New York City.

DE LA ROSA, FRANCISCO U., '91—Oaxaca, Mexico.

DE HART, JOHN S., JR., '90—Draughtsman, Isbell-Porter Co., Newark, N. J.

DEMAREST, THOMAS, W., '88—Pan Handle Railroad Shops, Columbus, O.

DENT, EDWARD L., '84—Owner and General Manager, The Washington Architectural Iron and Bridge Works, Washington, D. C.

DENTON, JAMES E., '75—Professor of Experimental Mechanics, Stevens Institute of Technology, Hoboken, N. J.

DICKINSON, G. K., M. D., Assoc., '75—63 Wayne Street, Jersey City, N. J.

DILWORTH, WILLIAM S., '85—Gordon & Dilworth, 563 Greenwich Street, New York City.

DINKEL, GEORGE, JR., '88—Chief Engineer, F. O. Matthiesen & Wiechers Sugar Refining Co., Jersey City, N. J.

DIX, WALTER S., '87—Draughtsman, Metropolitan Traction Co., New York City.

DIXON, J. ALFRED, '91—Engineer, Pintsch Compressing Co., 160 Broadway, New York City.

DIXON, ROBERT, '81—Manager, Pintsch Compressing Co., 160 Broadway, New York City.

DOTY, PAUL, '88—Assistant Superintendent (for United Gas Improvement Co.), Paterson Gas Light Co., Paterson, N. J.

DOUGHERTY, WILLIAM M.,* '78—Lawyer, Jersey City, N. J.

DOUGLAS, EDWIN R., '93—Howe Scale Co., Rutland, Vt.

DOW, ALEXANDER, '91—Dow Type Composing Co., 31 East Seventeenth Street; Mechanical Engineer, 56 Pine Street, New York City.

DREYSPRING, ERNEST, '85—Williamson Iron Co., Birmingham, Ala.

DRUMMOND, EDWIN M., '88—Drummond Manufacturing Co., Louisville, Ky.

DUCOMMUN, EDWARD, '88—Assistant Engineer, American Sugar Refining Co., Jersey City, N. J.

EASTWOOD, JAMES, '89—B. Eastwood, Silk Machinery, 302 Straight Street, Paterson, N. J.

EBSEN, HENRY L., '89—Draughtsman, Inman and International Steamship Co., Jersey City N. J.

EBSEN, WILLIAM, '90—The George F. Blake Manufacturing Co., 95 Liberty Street, New York City.

ELLIOTT, THEODORE A., '80—Consulting Mechanical Engineer, Eagle and Adams Streets, Buffalo, N. Y.

ELLSWORTH, OLIVER, '94—Draughtsman, with Ingersoll & Sergeant Drill Co., Easton, Pa.

ELSON, LOUIS E., '91—Elson & Brewster Engineering Co., 143 Liberty Street, New York City.

EMMET, C. TEMPLE, '91—Edison General Electric Co., 44 Broad Street, New York City.

ESTRADA, E. DUQUE, '83—Estrada & Gray, Inspecting Engineers, 307 Lewis Block, Pittsburg, Pa.

EVERETT, CHARLES J., JR., '90—Manager, Lowville Iron Works Co., and for J. W. Rentow, Havemeyer Building, New York City.

FABER DU FAUR, ADOLPH, JR., '84—Consulting Engineer and Solicitor of Patents, Vanderbilt Building, New York City.

FANNING, W. S. '93—With Norton Bros., Maywood, Ill.

FARRAR, WILLIAM M., '90—Mechanical Engineer, John J. Radley & Co., Architectural and Structural Iron, 214-220 East Thirty-seventh Street New YorkCity.

FEARN, RICHARD L., '84—The United Press, Washington, D. C.

FELLHEIMER, W. J., '89—Mechanical Engineer, 513 Broadway, New York.

FERNANDEZ, LUCAS, '92—Assistant Engineer of Public Works, San Jose, Costa Rica.

FERRIS, HARRY C., '88—Superintendent and Engineer, Maintenance of Way, Toledo, Columbus, and Cincinnati Railroad, Kenton, O.

FEZANDIÉ, J. HECTOR, '75—Instructor in Physics, Astronomy, and Mathematics, Cutler's School, 20 West Forty-third Street, New York City.

* Received Degree of Bachelor of Science.

FIELD, CORNELIUS J., '86—Consulting and Supervising Engineer, Havemeyer Building, 26 Cortlandt Street, New York City.

FIELD, W. B. O., '94—Assistant Engineer, Chief Engineer's office, N. Y. C. & H. R. R. R. Co., New York City.

FIELDER, GEO. B., '94—Mechanical Engineer, Sprague Electrical Elevator Co., New York City.

FIRESTONE, J. F., '87—Peters Dash Co. and Columbus Buggy Co., Columbus, O.

FLACK, J. DAY, '87—252 West Eighty-fifth Street, New York City.

FOSTER, ERNEST H., '84—Mechanical Engineer, H. R. Worthington, Hydraulic Works, Brooklyn, N. Y.

FRAENTZEL, FREDERICK C., '83—Firm of Campbell & Co., Solicitors of Patents and Mechanical Engineers, Newark, N. J.

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THOMAS, BENJAMIN F.,* '80—Professor of Physics, Ohio State University, Columbus, O.

THOMAS, CHARLES W., '84—Mechanical Engineer, 132 Nassau Street, New York City.

THOMPSON, EDWARD P., '78—Patent Attorney and Consulting Electrician, 5 Beekman Street, New York City.

THUMAN, FREDERICK, '90—Engineering Department, Humphreys & Glasgow, Gas Engineers, 9 Victoria Street, London, England.

TODD, GEORGE L., '90—Paul Steam System Co., 10 Federal Street, Boston, Mass.

TORRANCE, HENRY, JR., '90—Mechanical Engineer, Hendrick Manufacturing Co., Ltd., Carbondale, Pa.

TORRANCE, KENNETH, '84—Engineer of Brooklyn Water Works, Brooklyn, N. Y.

TRAUTVETTER, CHARLES, '90—The Bristol Co., Waterbury, Conn.

TRAUTWEIN, ALFRED P., '76—Superintendent, The Hendrick Manufacturing Co., Ltd., Carbondale, Pa.

TRUBE, G. A., '90—Night Superintendent, Rail Mill, South Works, Illinois Steel Co., South Chicago, Ill.

TUCKER, BENJAMIN W., '84—Consulting Engineer, 39 Broad Street, Newark, N. J.

TUTTLE, WILLARD S., '84—Tuttle & Bailey Manufacturing Co., Brooklyn, N. Y.

TWITCHELL, R. S., '90—Instructor, The Hill School, Pottstown, Pa.

UEHLING, EDWARD A., '77—Mechanical Engineer, Birmingham, Ala.

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VAIL, EUGENE L., '76—Artist, Paris, France.

VAN ATTA, HARRY, '81—Superintendent, J. L. Mott Iron Works, Mott Haven, New York City.

VAN-DER WILLIGEN, T. A., '88—With C. L. Strobel, Consulting Engineer, Home Insurance Building, Chicago, Ill.

VAN VLECK, FRANK, '84—Mechanical Engineer, Pacific Railway Co., Los Angeles, Cal.

VAN VLECK, JOHN, '84—Edison Electric Illuminating Co., Elm Street, New York City.

VAN WINKLE, FRANKLIN, '77—Consulting Engineer and Mill Architect, 126 Liberty Street, New York City.

VIDAL, PHILIP, '92—Draughtsman, Camden Iron Works, Camden, N. J.

VILLA, JOSE MARIA, '78—Professor of Mathematics, National University, United States of Colombia.

VOGELIUS, C. F., '92—49 Fremont Street, Bloomfield, N. J.

WADE, W. HARVIE, '85—Engineering Department, Humphreys & Glasgow, Gas Engineers, 9 Victoria Street, London, England.

WAEFELAER, F. LOUIS, JR., '92—With Carl H. Schultz, 440 First Avenue, New York City.

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WALKER, LOUIS B., '91—Globe, Arizona.

WALL, GEORGE L., '93—Southern R. R. Shops, Knoxville, Tenn.

WALLIS, JAMES T., '91—Pennsylvania Railroad Shops, West Philadelphia, Pa.

WALLIS, J. MATHER, '76—Superintendent of Motive Power, Pennsylvania Railroad, Altoona, Pa.

WALLIS, PHILIP, '79—Master Mechanic, Chicago, Burlington and Quincy Railroad, Beardstown, Ill.

WARRINGTON, JAMES N., '83—Secretary, Vulcan Iron Works, 86 North Clinton Street, Chicago, Ill.

WEBSTER, HOSEA, '82—H. R. Worthington, 86 Liberty Street, New York.

WEEKS, FRANK J., '93—26 West Twenty-second Street, New York City.

WELLS, PIERSON L., '92—Assistant Engineer, Scharff Manufacturing Co., *Times* Building, New York City.

WESTCOTT, J. T., '90—General Manager and Treasurer, The Economical Gas Apparatus Construction Co., 269 Front Street E., Toronto, Canada.

WETTLAUFER, LOUIS, '92—1221 Garden Street, Hoboken, N. J.

WETZLER, JOSEPH, '82—Editor of the *Electrical Engineer*, 203 Broadway, New York City.

WHEATLEY, CRAWFORD, '87—General Manager, Americus Refrigerating Co., Americus, Ga.

WHIGHAM, WILLIAM, '88—Draughtsman, Carnegie Steel Co., Munhall, Pa.

WHITCOMB, H. D., '92—Inspector, R. W. Hildreth & Co., 50 Broadway, New York City.

WHITING, CHARLES W., '84—Hendrick Manufacturing Co., Carbondale, Pa.

WHITE, EDWARD F., '86—Consulting Engineer, 175 Plumb Street, Cincinnati, O.

WHITE, HENRY C., '81—Manager, New York Office, The Phœnix Iron Works Co., 15 Cortlandt Street, New York City.

WHITE, MAUNSEL, '79—Engineer of Tests, Bethlehem Iron Co., Bethlehem, Pa.

WHITE, WILLIAM F., '86—Manufacturer and Importer of Machinery, Mexico City, Mexico.

WHITLOCK, E. H., '90—Consulting Engineer, 200 West Fourth Street, Cincinnati, O.

WHITLOCK, ROGER H., '82—Professor of Mechanical Engineering, State Mechanical and Agricultural College, Texas.

WHITNEY, A. R., JR., '90—General Manager, Puget Sound Wire-Nail and Steel Co., and Manager Everett Railway and Electric Co., P. O. Box 63, Everett, Wash.

WHITNEY, O. C., '92—Assistant Engineer, Pintsch Compressing Co., 160 Broadway, New York City.

WILBOR, ANSON G., '93—59 Lancaster Street, Albany, N. Y.

WILES, EDWIN L., '76—Superintendent, Steel Department, Riverside Iron Works, Wheeling, W. Va.

WILKES, J. FRANK, '85—Superintendent, Mecklenberg Iron Works, Charlotte, N. C.

WILKES, J. RENWICK, '93—Trenton Iron Co., Trenton, N. J.

WILLIAMS, HARVEY D., '85—Assistant Professor of Drawing and Machine Design, Sibley College, Cornell University, Ithaca, N. Y.

WILLIAMS, FRANK H., '81—Flenniken Turbine Co., Dubuque, Iowa.

WILLIS, EDWARD J., '88—General Manager, Talbott & Sons Co., Richmond, Va.

WILLIS, PAUL, '85—614 First National Bank Building, Chicago, Ill.

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WOLFF, ALFRED R., '76—Consulting Mechanical Engineer, Fulton Building, New York City.

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WOOD, F. H., '93—Upper Montclair, N. J.

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WORTENDYKE, IRA F., '89—Superintendent, New Gas-Light Co., 5 North Main Street, Janesville, Wis.

WREAKS, HUGH, '90—Brooklyn, N. Y.

WREAKS, WILLIAM B., '89—Westinghouse Electric & Manufacturing Co., Pittsburgh, Pa.

WRIGHT, ERNEST N., '83—"Hazelbrook," Germantown, Philadelphia, Pa.

WUICHET, EDWARD S., '91—Vice-President, The Miami Valley Boiler Co., Dayton, O.

WYANT, ROBERT E., '89—Superintendent, Colorado Springs Gas & Electric Co., Colorado Springs, Col.

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R. H. THURSTON, A. M., LL. D., E. D., '85, Director of Sibley College, Cornell University, Ithaca, N. Y.

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BOOK NOTICES.

RECENT PUBLICATIONS.

THE THEORY OF TURBINES. By DE VOLSON WOOD, Professor of Mechanical Engineering, Stevens Institute of Technology. Pp. 64. Published by John Wiley & Sons, New York.

The author deduces a general equation for the work done by a hydraulic turbine, and the efficiency for the same, including internal resistances, and draws from it some general conclusions. But the more valuable part of the work consists in the numerical values deduced from the general equation by assuming certain values for the constants of the wheel. These results, being tabulated, furnish the basis for further discussions which will be of practical value to the designing engineer. Among other things, it is shown that the efficiency of the inflow-wheel is generally higher and is less affected by variations in the constants than the outflow; and hence it is a better type for general use. Several special types are also discussed.

FACTS AND FIGURES RELATING TO ELECTRIC RAILWAY WORK. L. W. SERRELL, M. E., '78.

This is a handy, practical booklet, embodying the hard-won experience of the author in the line indicated.

THE THEORY AND PRACTICE OF LETTERING. By CHRISTOPHER E. SHERMAN, C. E., Columbus, Ohio.

This is a book of some twenty-four pages, embodying selections from the works of others available to the author, and compiled with special reference to the needs of students in engineering.

While the book could doubtless be made of greater value to the student by the addition of detail instructions as to the principal strokes to be executed in forming the letters, it contains much practical information and many useful suggestions, which will aid in crystallizing the vague impressions of beginners on the subject of Lettering.

THE CATALOGUE of Keuffel & Esser Co., for 1895, is deserving of mention here, for the reason that it contains much more information concerning the materials and instruments employed by draughtsmen and engineers than is available in the same compass elsewhere.

The distinctions noted in this book between the qualities of the various articles of a class, and their adaptability to special uses, should materially assist those who have occasion to make selections, yet lack familiarity with the articles; and the amount of explanatory matter introduced, and the completeness with which the newest instruments are represented is warrant for its examination by draughtsmen, however well posted.

ACCESSIONS TO THE INSTITUTE LIBRARY, JULY 1, 1894, TO JANUARY 1, 1895.

Books Purchased.

Stabilité des Constructions Resistance des Materiaux. By A. Flamont. Paris.
Minutes of Proceedings of the Institution of Civil Engineers. Vol. 116. Part II. 1893–1894. London.
Handbuch der Anorganishe Chemie. By Dr. O. Dammer.
Select Methods in Inorganic Analysis. By W. Crookes.
Marine Propellers. By Sidney W. Barnaby.
Resistance of Ships. By D. W. Taylor.
Transactions of Institution of Naval Architects. 3 Vols. 1891, 1892, 1893.
Catalogue of Scientific Papers. Vols. 9 and 10. *Royal Society, London.*
"*Solutions.*" By W. Ostwald.
Specifications and Drawings of Patents, U. S. Patent Office. January, March, April, 1893.
Official Gazette, U. S. Patent Office. Vols. 59 and 66.
Arithmetic of Magnetism and Electricity. By Morrow and Reid.
Electricity for Engineers. Parts I. and II. By Chas. Desmond.
A Laboratory Manual of Physics and Applied Electricity. By E. L. Nichols.
Lightning Conductors and Lightning Guards. By O. J. Lodge.
On the Development and Transmission of Power from Central Stations. By W. C. Unwin, F. R. S.
Polyphased Alternating Currents. By E. Hospitalier.
Journal für Chemie. Vol. 157. Leipzig.
The Chemistry of Paper-making. By R. B. Griffin.
Watts' Dictionary of Chemistry. Vol. 4. By Muir & Morley.
Petroleum; Its Products, etc. By William T. Brandtt.
Chemische Präparatenkunde. By Dr. Hugo Erdmann.
Namen Register, 1874–1893. Annalen der Physik und Chemie. By G. Wiedemann.
Annalen der Physik und Chemie. Vols. 287–288. By G. Wiedemann.
Annalen der Chemie. Vols. 278–279. Leipzig.
Annales de Chemie et de Physique. 1894. Paris.
Chemisches Central-Blatt. Jan.-July, 1894. Leipzig.
The Steam Engine. By J. A. Ewing.
Report of the British Association for the Advancement of Science. 2 Vols. 1888 and 1893. London.
Proceedings of the Royal Society of London. Vol. 55.
Journal of the Franklin Institute. Vol. 137.
Transactions of the American Institute of Mining Engineers. 1893.
The Electrician. Vol. 32. London.
Scientific American. Vol. 70. (Jan.-July, '94.)
The Engineer. Vol. 77. (Jan.-July, '94.)
Engineering. Vol. 57. (Jan.-July, '94.)

A Text-Book on Roofs and Bridges, Part I. By Mansfield Merriman.
The Electrical World. Vol. 23 (Jan.–July, '94).
The Electrical Engineer. Vol. 17 (Jan.–July, '94).

Books Contributed.

By President Morton. *Proceedings A. A. A. S.* Vol. 41. (1892.)
By Josef Pechan. *Leitfaden des Dampfbetriebes.* By Josef Pechan.
By Josef Pechan. *Leitfaden der Electromaschinentechnik.* By Josef Pechan.
By Josef Pechan. *Leitfaden des Maschinenbaues.* By Josef Pechan.
By Smithsonian Institute. *Annual Report of the Bureau of Ethnology.* (1888–1889.) By J. W. Powell.
By Smithsonian Institute. *Proceedings of the U. S. National Museum.* 1893.
By Smithsonian Institute. *Report for 1893.*
By STEVENS INDICATOR. STEVENS INDICATOR. Vol. 11. (1894.)
By Department of the Interior. *Compendium of the 11th Census* (1890). Part II. By Carroll D. Wright.
By U. S. Geological Survey. *Mineral Resources of the U. S. for 1893.* By David. T Day.
By Navy Department. *Annual Report of the Chief of the Bureau of Steam Engineering.*
By Department of Labor. *Eighth Annual Report of the U. S. Commissioner of Labor* (1892). By Carroll D. Wright.
By War Department. *Annual Report of the Chief of Ordnance, U. S. A.* (1893.)
By State Board of Health, Mass. *Twenty-Fifth Annual Report of the Massachusetts Board of Health.*
By Bureau of Education. *Higher Education in Tennessee.* By L. C. Merriam, Ph. D.
By Bureau of Education. *History of Education in Connecticut.* By B. C. Steiner, A. M.
By Bureau of Education. *Higher Education in Iowa.* By L. F. Parker.
By U. S. Department of Agriculture. *Report of the Chief of the Weather Bureau for 1893.* By M. W. Harrrington.
By Angel and Jones, '94. Thesis. *Test of the Sea-going Tug Plymouth.*
By Klumpp, Hartpence and McGowan, '94. Thesis. *Tests of Electric Railway Motor.*
By E. P. Buffet, '94. Thesis. *Magnetic Properties of Nickel Steel.*
By Anderson and Burke, '94. Thesis. *Test of a "B. & W." Boiler.*
By Cottier and Ellsworth, '94. Thesis. *Gas Holder Guide Framing.*
By Peabody and Merritt, '90. Thesis. *Electro-Motive Force of the Alternating Current.*

INDEX TO CURRENT ENGINEERING LITERATURE.

THE following is an Index of the more important articles appearing in the current engineering papers and magazines, and is compiled with the object of aiding our readers to know where to find the most recent information pertaining to the subjects interesting them in the various departments of engineering.

LIST OF PERIODICALS INDEXED.

A list of the papers and magazines indexed is here given, in alphabetical order, together with the office of publication, from which any paper may be obtained, at the price stated below.

Am. Eng. & R. R. Jour.—American Engineer and Railroad Journal. Monthly. 47 Cedar Street, N. Y. Single copy, 25 cents.

Am. Gas Light Jour.—The American Gas Light Journal. Weekly. 32 Pine Street, N. Y. Single copy, 10 cents.

Am. Jour. of Sc.—The American Journal of Science. Monthly. New Haven, Conn. Single copy, 50 cents.

Am. Mach.—American Machinist. Weekly. 96 Fulton Street, N. Y. Single copy, 10 cents.

Cassier's Mag.—Cassier's Magazine. Monthly. World Building, N. Y. Single copy, 25 cents.

Elec. Eng.—The Electrical Engineer. Weekly. 203 Broadway, N. Y. Single copy, 10 cents.

Elec. Review.—Electrical Review. Weekly. 22 Paternoster Row, London, E. C. Single copy, 4d.

Elec. World.—The Electrical World. Weekly. 177 Times Building, N. Y. Single copy, 10 cents.

Electrician.—The Electrician. Weekly. 1, 2, and 3 Salisbury Court, Fleet Street, London, E. C. Single copy, 4½d.

Electricity.—Electricity. Weekly. 6 Park Place, N. Y. Single copy, 10 cents.

Engineer (Am.).—The Engineer (American). Weekly. 106 and 108 Fulton Street, N. Y. Single copy, 10 cents.

Engineer (Lon.).—The Engineer (London). 33 Norfolk Street, Strand, W. C., London. New York Agency, International News Co., 83 Nassau Street, N. Y. City. Single copy, 6d.

Engineering.—Engineering. Weekly. 35 and 36 Bedford Street, Strand, London, W. C. Single copy, 6½d. Agency, Mr. W. H. Wiley, 53 East Tenth Street, N. Y.

Eng. Mag.—The Engineering Magazine. Monthly. 47 Times Building, N. Y. Single copy, 25 cents.

Eng. Mech.—Engineering Mechanics. Monthly. 430 Walnut Street, Philadelphia, Pa. Single copy, 10 cents.

Eng. & Min. Jour.—Engineering and Mining Journal. Weekly. 27 Park Place, N. Y. Single copy, 15 cents.

Eng. Rec.—Engineering Record. Weekly. 4½ copy, 12 cents.

Heating & Vent.—Heating and Ventilation. Monthly. World Building, N. Y. Single copy, 10 cents.

Ice & Refrig.—Ice and Refrigeration. Monthly. 206 Broadway, N. Y. Single copy, 25 cents.

Industry.—Industry. Monthly. 40 California Street, San Francisco, Cal. Single copy, 20 cents.

Iron Age.—Iron Age. Weekly. 100 Reade Street, N. Y. Single copy, 10 cents.

Jour. Ass'n Eng. Soc.—Journal of the Association of Engineering Societies. Monthly. 419 Locust Street, Philadelphia, Pa. Single copy, 30 cents.

Light, Heat & Power.—Light, Heat and Power. Monthly. Drexel Building, Philadelphia, Pa. Single copy, 25 cents.

Locom. Eng.—Locomotive Engineering. Monthly. 256 Broadway, N. Y. Single copy, 20 cents.

Machinery.—Machinery. Monthly. 411 Pearl Street, N. Y. Single copy, 5 cents.

M'n'f'r & Builder.—The Manufacturer and Builder. Monthly. 83 Nassau Street, N. Y. Single copy, 15 cents.

Nat. Car & Loc. B'ld'r.—The National Car and Locomotive Builder. Monthly. 140 Nassau Street, N. Y. Single copy, 20 cents.

Nature.—Weekly. 29 Bedford Street, Strand, W. C., London, Eng. Single copy, 6d.

Power.—Power. Monthly. World Building, N. Y. Single copy, 10 cents.

Prog. Age.—Progressive Age. Semi-monthly. 280 Broadway, N. Y. Single copy, 15 cents.

R. R. Car Jour.—The Railroad Car Journal. Monthly. 132 Nassau Street, N. Y. Single copy, 10 cents.

Railroad Gazette.—Railroad Gazette. Weekly. 73 Broadway, N. Y. Single copy, 10 cents.

Railway Age.—The Railway Age and Northwestern Railroader. Weekly. Monadnock Block, Chicago, Ill. Single copy, 10 cents.

Railway Eng. & Mech.—Railway Engineering and Mechanics. Monthly. The Rookery, Chicago, Ill. Single copy, 10 cents.

Sc. Am.—Scientific American. Weekly. 361 Broadway, N. Y. Single copy, 10 cents.

Sc. Am. Sup.—Scientific American Supplement. Weekly. 361 Broadway, N. Y. Single copy, 10 cents.

Stevens Ind.—Stevens Indicator. Quarterly. Stevens Institute, Hoboken, N. J. Single copy, 50 cents.

St. Ry. Jour.—Street Railway Journal. Monthly. World Building, N. Y. Single copy, 35 cents.

Trans. A. S. M. E.—Transactions of the American Society of Mechanical Engineers. Annual. 12 W. Thirty-first Street, N. Y. Single copies, 5 cents for each 16 pages or fraction thereof.

Uni. Wis. Bul.—University of Wisconsin Bulletin (Engineering Series). University of Wisconsin, Madison, Wis.

THE STEVENS INDICATOR.

VOL. XII. APRIL, 1895. No. 2

THE NEW YORK PUBLIC LIBRARY

ASTOR, LENOX AND TILDEN FOUNDATIONS.

ENGINEERING FALLACIES.

SECOND PAPER.

BY PRESIDENT HENRY MORTON, PH.

In the report of my lecture on Engineering Fallacies which was published in the INDICATOR of October, 1894, occurs the following remark: "It may seem almost needless to say so much on the subject of these gross and conspicuous fallacies; but, while the stock of the Keely Motor Co., in the face of repeated exposures and years of unfulfilled promises, has to-day a value in the market, and when not only such daily papers as are notorious for their lack of truth, honor or decency, but even respectable journals, will publish articles seriously advocating such plans, it is evident that even such fallacies need to be met and exposed by the intelligent engineer." Since the publication of these words, the necessity of such explanations and exposures of even such gross and conspicuous fallacies has been very emphatically illustrated.

Thus, to begin with, even so respectable a journal as *The Engineer*, published in London, in its issue of January 11th, had an editorial article on my paper above named, in which my conclusions as to the impossibility of "perpetual motion" were called in question, and it was maintained, on the contrary, that the discovery of mechanical and like combinations by means of which power might be got for nothing is a possibility that no one would be justified in denying.

That such a position should be taken, at this date, by the editor of an engineering journal of such standing is so remarkable a phenomenon that I will quote the language of *The Engineer* on this subject.

After some general remarks on the doctrine of Conservation of Energy, etc., the writer proceeds to illustrate his position as follows:

"Let it be supposed that the cylinder of a beam engine was removed, and replaced by a series of very powerful magnets arranged round the piston. If, now, the first ring of magnets, and then the second and third, and so on, attracted the piston successively, the engine would work just as though driven by steam. Let the magnets be permanent, and let the piston be surrounded by a cylindrical shield, which, while itself non-magnetic, would also cut off the influence of the magnets as it passed each on its way down. Under these conditions we would have a machine which would comply with the perpetual-motion man's desire. In one sense it would flatly contradict the conservation of energy theory—we should get power for nothing. The only thing needed is the magnetic shield. Now why is it that no such shield exists? Is it because the existence of the shield would upset the conservation of energy?"

To the above double question we answer at once, yes. In other words, the law of the conservation of energy is like all other laws of science, simply the generalized statement of universal antecedent experience. If they deserve to be accepted as laws, it is simply because antecedent experience has been so extended and invariable that we are entitled to believe that it will continue to be invariable, and that, therefore, we are warranted in assuming that a statement or assumption which would flatly contradict such laws is untrue or impossible.

It may, of course, be said that our experience can never be so extended as to absolutely exclude the possibility of some modification of any given law; but that simply goes to the question as to the truth of the law, and of our reliance upon it.

As long as we believe the law to be true, we must assert of any proposition subverting such law that it is untrue or impossible.

To say that any one can "hold the doctrine of the conservation of energy with unquestioning faith" and yet regard as possible a condition of facts that would "flatly contradict it," is to use language in a manner only appropriate to a lunatic asylum.

Our friend of *The Engineer* is probably not aware that his

suggestion about the engine operated by permanent magnets and a magnetic shield is not new.

In 1879 a Mr. Gary brought before the public in Boston, Mass., a magnetic motor, which was represented as operating in just this way. A magnetic shield was interposed between permanent magnets and movable pieces of soft iron and withdrawn at the proper time, so as to secure continuous motion. A five-page illustrated article headed "Gary's Magnetic Motor," treating the subject in all seriousness as involving a great and useful discovery, was published in the long established and highly respectable journal, *Harper's Monthly*, in its issue of March, 1879, pp. 601–605 inclusive.

In this article it was truly stated that a plate of soft iron would constitute a magnetic shield, and that, if introduced between a permanent magnet and an armature or piece of soft iron attracted by said magnet, it would cut off such attraction, which would, of course, be renewed on the removal of the shield. Various forms of motors operating on this principle were figured and described.

The operation of these machines was described, at the time, by an eye-witness, to the present writer, who, however, did not find his belief in the conservation of energy consistent with the acceptance of assertions flatly contradictory to the same, even from an eye-witness, but, by a careful examination, elicited the fact that all the machines which ran without manual aid had electro-magnets in them excited by a galvanic battery. The inventor had explained that this was only to secure greater intensity of magnetization than could be obtained with permanent magnets; but the opening for fraud thus presented was of course manifest. In the machines not operated with electro-magnets the withdrawal of the magnetic shield was effected by hand.

The whole matter was not difficult to treat on general principles. It is, of course, true that iron will act as a "magnetic shield"; but when it does so, it is itself attracted, and the work expended in withdrawing it from before the magnet, as might reasonably be expected, is equal to that which could be developed by the changes of attraction secured by its manipulation.

In this case, the condition required by *The Engineer*, of a magnetic shield not itself magnetic, was not supplied, neither

has such a shield been produced since, nor need it be expected that such a combination will ever be discovered. If it should be, perpetual motion would be realized and "the conservation of energy" would become an exploded theory.

It is interesting to notice that the fundamental principles involved in the actions which really took place in the Gary motors are fully expressed in "Rudimentary Magnetism," by Sir W. Snow Harris, published in the *Weals Series of Manuals*, 1850, pp. 29 to 36.

Indeed, we find the foundation of it all in the "Principia" of Sir Isaac Newton, Proposition XXIII., Theorem XVIII., Scholium, where we read: "We have an example of this in magnetic bodies. Their attractive virtue is terminated nearly in bodies of their own kind that are next them. The virtue of the magnet is contracted *by the interposition of an iron plate*, and is almost terminated at it."

It is hardly necessary to say that the Gary Magnetic Motor turned out to be a fraud, the energy required for the automatic motors being supplied by the galvanic battery whose connections with the electro-magnets were broken at the proper time, while, in the others, the manual force applied to the shields was in fact, the origin of their movement.*

Again, our friend of the *Engineer* says," Thus, there is no reason known to mankind why gravity should not be interrupted; and, if any inventor announced to-morrow that he had discovered or invented the material, no man living would be justified in calling him a liar, on the ground that he said he had done that which is impossible."

To this I would reply that any man who "held the doctrine of conservation of energy with an unquestioning faith" would be fully justified in using any terms consistent with propriety, in indicating his absolute disbelief in the statement made, because the same "would flatly contradict the conservation of energy," and would therefore involve a claim that "he had done that which is impossible."

* When this Gary Motor first appeared the present writer published an explanation of the above tenor in the *Journal of the Franklin Institute*, 1879, Vol. 77, p. 337, and in the *Scientific American*, 1879, Vol. 40, p. 324.

There *is* a "reason known to man why gravity should not be interrupted," namely, that such a performance would flatly contradict the doctrine of the conservation of energy, and also be contrary to universal experience; and, therefore, when I see the performances of illusionists, or read of those by Indian Fakirs, in which gravity seems to be interrupted, I do not trouble myself in the least as to the ground of my faith in "the conservation of energy," but simply try to detect the trick.

What I have written above shows that the "doctrine of conservation of energy" is one calling for "missionary effort," even in the scientific circle surrounding such an instructor as "*The Engineer;*" and, stepping down to a lower level, I find another call for enlightenment in one of our most prominent daily journals.

Thus, on the editorial page of the *New York Sun*, March 27th, is a letter signed Geo. H. Peabody, and headed "KEELY HEARD FROM AGAIN," in which is announced the speedy exhibition of a "250 horse power commercial engine." The chief evidence adduced in this letter in support of the above claims is a quotation from the late Dr. Leidy, justly celebrated as one of the first anatomists and surgeons of the world, which reads as follows: "Mr. Keely's discoveries would astonish the scientific world, and the great worth of them could not be estimated."

That Dr. Leidy made such a statement, I have no doubt whatever, nor that he stood at the head of his profession; but, that he was competent to investigate such a subject as the Keely motor tricks, is quite another matter.

Having some personal acquaintance with Dr. Leidy, I know him to have been a man of perfect candor, and of a trustfulness of disposition which led him to accept any statement made to him as presumably correct; and to go on believing, even when he saw that what he had been told might possibly be untrue.

This is strikingly illustrated by a correspondence I had with him on the very subject of the Keely motor, as I will now relate. In October, 1889, at the request of some friends, I had agreed to attend an exhibition of the Keely motor, but, at the last moment, was prevented from doing so.

A neighbor, however, who was a firm believer in Mr. Keely, went to the "seance," and the next day reported to me in a vivid manner all that was done, relating, also, that Dr. Leidy was present and had expressed surprise and conviction.

So clear was the account of my friend, that I felt certain I could judge from his description how the operation was carried out, and I therefore wrote to Dr. Leidy, explaining my solution, and asking him a series of questions calculated to bring out any objections to my theory.

He replied admitting that my explanation was consistent with everything he had seen, but expressing the wish that I would come on and see for myself these "wonderful experiments." In other words, the Doctor, while realizing that the effects *might* be produced by a trick, could not believe that deceit had been employed, and that Mr. Keely was anything else than the honest investigator he pretended to be.

This use, or abuse, of the reputation of men distinguished in some very different line of studies, which, in many cases, directly unfits them for the investigation of such fallacies, is a very common device, of which another example has come to my notice within a few days. In my previous article, I related the incidents of a visit to the workshop in Newark where Mr. Paine was exhibiting a perpetual-motion electric motor. A few days since a letter from Mr. Paine appeared in a local daily, in which he denies the fact of my visit, and proceeds to substantiate the value of his invention by reciting the names of a number of distinguished men, all now dead, who took a financial interest in its development.* It so happens that I knew nearly

*In kindness to Mr. Paine, I will assume that the question he has raised as to the fact of my visit and what I saw in the building in which his electro-magnetic engine was exhibited is one of memory rather than veracity, and, in this view, it is easily settled by reference to a letter published about the time of my visit by Prof. Henry A. Rowland, C. E., now of Johns Hopkins University, Baltimore, Md., and which appeared in the *Scientific American* for 1871, Vol. 25, p. 21.

In this letter Prof. Rowland relates how, on applying for admission, about 12 o'clock, he was told that the machine was not running then; but that returning after one o'clock, he was admitted and taken up to the second floor of a brick building, where he found the inventor, some of his friends, and his machine; also, that the machine was enveloped in a cast-iron case, giving

all these gentlemen at the time referred to, and most that I said outside of my own observations was communicated to me by them. While, however, in questions of finance, politics, military affairs, details of mechanical manufacture and philanthropy, I would gladly sit at their feet as a learner, there was not one of them whom I would trust to detect manipulations such as were involved in Mr. Paine's exhibitions.

A general, a governor, a millionaire, a constructor of small machines, and even the most benevolent and public-spirited

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it the general appearance of a fan blower, and was seemingly operated by a battery, with a great development of energy.

Prof. Rowland then continues as follows: "The exhibition being over, on going down stairs, in company with the rest, I tried the door of the room below, but found it locked, and the windows covered with papers. I desired to get in, but was met with the assurance that the room was rented by a man who was then absent.

"This, I believe, is the last visit paid by an outsider to this wonderful invention. I have been there several times since, but there has been no admittance to me or to anyone else. I have since been to the owner of the building, and find that Mr. Paine rents the room to which I sought admittance, and also rents power in that same room, which is directly below that containing his machine. The engine from which the power comes generally stops work at twelve and starts again at one, but sometimes works all day.

"My visits there have established the following facts: First. That my friend and I were denied admittance at twelve o'clock, but were invited to come at one. Second. That the shaft in the room below does not revolve between the hours of twelve and one. Third. That the room below, containing power, was rented by Mr. Paine; but that he kept it carefully locked, and misguided me as to the tenant. Fourth. That the working parts are concealed in an unnecessarily strong case, well adapted to the concealment of another source of power."

This is followed by much more to the same effect, but enough has been quoted to show that it is not *my* memory which was at fault when I related what I had seen, at the time of my visit shortly before this one made by Prof. Rowland. That Mr. Paine should have forgotten the fact that, after declining his invitation in the morning, I nevertheless accepted in the afternoon, after my lecture preparations were completed, is entirely natural.

As to the substantial accuracy of my memory about the collapse of Mr. Paine's company, the following brief quotation will, I think, suffice.

Scientific American, 1872, Vol. 26, p. 321. "The *Telegrapher* states that the Paine Electro-Magnetic Engine Company Bubble, late of Newark, N. J., has gone up; that the inventor has left for the East, where the wise men came from; and that the stockholders have experienced a galvanic shock in the shape of a total loss of their interests."

of manufacturers, were far more likely (as in this case was actually proved) to be lambs easily shorn by a clever adventurer, than competent detectives able to expose his methods.

This is in fact one of the pitfalls that the young engineer needs to be warned of, and to avoid; namely, the risk of being led to accept a statement as true, because it is credited and perhaps endorsed by some one prominent in business, or who is before the public (with good cause), for eminent achievements in some special field. The liability to be misled on unfamiliar subjects existing in high places is simply incredible, if the evidence were not overwhelming. For example, some few years ago, I was called on to give testimony in a case which grew out of the circumstance that a gentleman of the highest standing in his community and the business head of a great chemical works had allowed himself to be persuaded, by means of fraudulent experiments, that, by a certain hocus-pocus process, a pound of ammonium sulphate could be made to yield twice the quantity of ammonia which it contained.

The fraud, in this case, consisted (as was shown during the trial), in packing a quantity of the ammonia-salt, out of sight, in the generating vessel, before the arrival of the gentlemen in whose presence the "*experiment*" was conducted. Curiously enough, the suit above referred to was brought by the representatives of the swindlers, to compel the confiding victim to pay some $40,000 for stock in a company which was to be formed for the development of the "*invention*." Thanks to an array of learned counsel and an intelligent jury, the complainant was not successful; but, I should be sorry to have to pay the expenses incurred by the successful litigant, to say nothing of the $5,000 cash he had given as "earnest" to the "promoters."

The fact is that for the investigation of such "inventions" a peculiar detective talent and experience are required; and, in all cases, it is prudent to have nothing to do with such schemes unless the entire conduct of the experiment is placed in the hands of the investigator. A demand for this will generally relieve any one from the importunities of "promoters" and "inventors" of this class.

ON THE BERTHELOT-MAHLER CALORIMETER FOR THE DETERMINATION OF THE CALORIFIC POWER OF FUELS.

BY PROFESSOR ALFRED M. MAYER.

I have often heard experimenters, especially those who style themselves practical men, say that the result of their work was "good enough." Good enough is a relative term and implies that *good* is known. That is, that the experimenter has the knowledge of *the magnitude of the errors* existing in the results of his experiments. Of this knowledge he is often ignorant. By "good enough" young engineers are sometimes led into serious errors. For instance, no one accustomed to precise work in calorimetry would say that the determination of the temperature of a furnace, ascertained by placing a piece of metal of known weight and specific heat in the furnace and then plunging it into a horse-bucket containing a known weight of water, and from the rise of temperature ascertained with an uncorrected thermometer, reading only to single degrees, would give the data with sufficient accuracy for "practical purposes" to compute the temperature of the furnace: for the equivalent in water of a wooden bucket, whose substance contains an unknown quantity of absorbed water, cannot be ascertained, and the thermometer does not give the temperature with sufficient accuracy. To obtain the temperature of the furnace good enough for the object in view, the thermometer should have been divided into tenths of a degree, and the water equivalent of the calorimeter (which should have been made of polished metal) should have been accurately known and the loss of heat by the radiaton of the calorimeter should have been determined. Yet I have read accounts of the good enough results of such rough work with the horse-bucket as giving the temperatures of furnaces.

The object of this paper is to give information which will enable one to decide when his experiments on the calorific power of fuels, determined with the Berthelot-Mahler Calorimeter, are good enough.

The Berthelot-Mahler Calorimeter was first described by P. Mahler in the *Bulletin de la Société d'encouragement pour l'Industrie Nationale*, Juin, 1892. Paris, Siège de la Société, Rue de Rennes, 44. Abstracts from this paper have been published in several engineering and industrial journals, and thus this calorimeter is generally known to mechanical engineers.

It differs from Berthelot's calorimeter only in having the interior of the steel bomb lined with enamel instead of with platinum; a modification of Berthelot's calorimetric bomb, which greatly lowered its price and allowed it to be extensively used.* So far as my knowledge permits me to form a judgment, this calorimeter is by far the best for the determination of the calorific power of fuels. It is already in use in industrial establishments in all parts of the world.

The Berthelot-Mahler calorimeter consists essentially of a bomb forged out of Martin-Siemens steel, $\frac{8}{10}$ of a centimetre thick and holding (in the bomb of the Stevens Institute of Technology) 638 cubic centimetres. This bomb is immersed in 2400 grams of water, contained in a vessel of polished brass. This brass vessel is placed inside of a water-jacket covered with thick felt. The water-jacket contains 16 litres of water. The water in the brass vessel previous to and during the experiment is constantly stirred by the rotation of an agitator with helicoidal blades. The agitator is made of the same kind of brass as forms the vessel holding the water.

In the bomb is placed, on a platinum dish, about a gramme of the combustible whose calorific power is to be determined; the cap of the bomb is then tightly screwed on and a flange on the cap is thus forced into close contact with a ring of lead on the bomb, so that the gas does not escape, even when under a pressure of over 100 atmospheres. The bomb is now connected with a cylinder of compressed oxygen and the gas allowed *very slowly* to flow into the bomb till a pressure of from 25 to 30 atmos-

* "Cette couche d'émail nécessaire à la conservation de l'appareil, remplace la chemise de plusieurs milliers de francs de platine qui garnit la bomb (de Berthelot) du Collège de France. L'enduit d'émail ne saurait s'opposer à la transmission de la chaleur, car il est entremement mince. On e jugera d'après le poids de cet enduit qui est de 20 grammes environ."

MAHLER.

pheres is shown on the pressure guage. It is not necessary to have more pressure of oxygen in the bomb. I have found that the combustion of one gramme of napthalene, under a pressure of 20 atmospheres, was perfect, and napthalene has a calorific power of 9690 calories. It is, however, better to have always a pressure in the bomb of at least 25 atmospheres. The bomb is now closed by screwing a conical valve into its seat, and the bomb is immersed in the water of the calorimeter. The agitator is worked till the bomb and water have the same temperature. The combustible is then exploded by fusing with an electric current a fine iron wire, coiled into a helix, which has been placed in the midst of the combustible. The heat produced by the combustion of the wire is to be subtracted from that given by the combustion of the fuel, thus: multiply the weight of the wire by the calorific power of iron (1576). If the wire weighs 0.025 gram, then $0.025 \times 1576 = 39.4$ calories is to be subtracted from the number of calories given by the fuel.

The history of the passage of the heat of the gases of combustion through the steel bomb into the surrounding water of the calorimeter is given in the curve in this paper.

It is here to be said that in using 2400 grammes of water in the calorimeter, the water, as it should do, covers the top of the bomb, and the water may short-circuit such an amount of the current that only a fraction of it passes through the wire and the latter is not fused. This is readily avoided by covering the rod which carries the current into the calorimeter with a tightly fitting rubber tube which insulates the rod from the water.

WATER EQUIVALENT OF THE CALORIMETER.

The method generally adopted by physicists to obtain the equivalent in water of a calorimeter is to multiply the weights of the different substances composing the calorimeter by their respective specific heats. The method of adding a known weight of hot or of cold water, of known temperature, to the water in the calorimeter and from the resulting temperature to compute the equivalent in water of the calorimeter is not accurate. The maximum and minimum determinations of the water equivalent, thus found in 20 experiments, will differ by three to five per cent. from the mean value, according to the skill of the

experimenter. I here give the determination I have made of the Berthelot-Mahler calorimeter of the Stevens Institute of Technology.

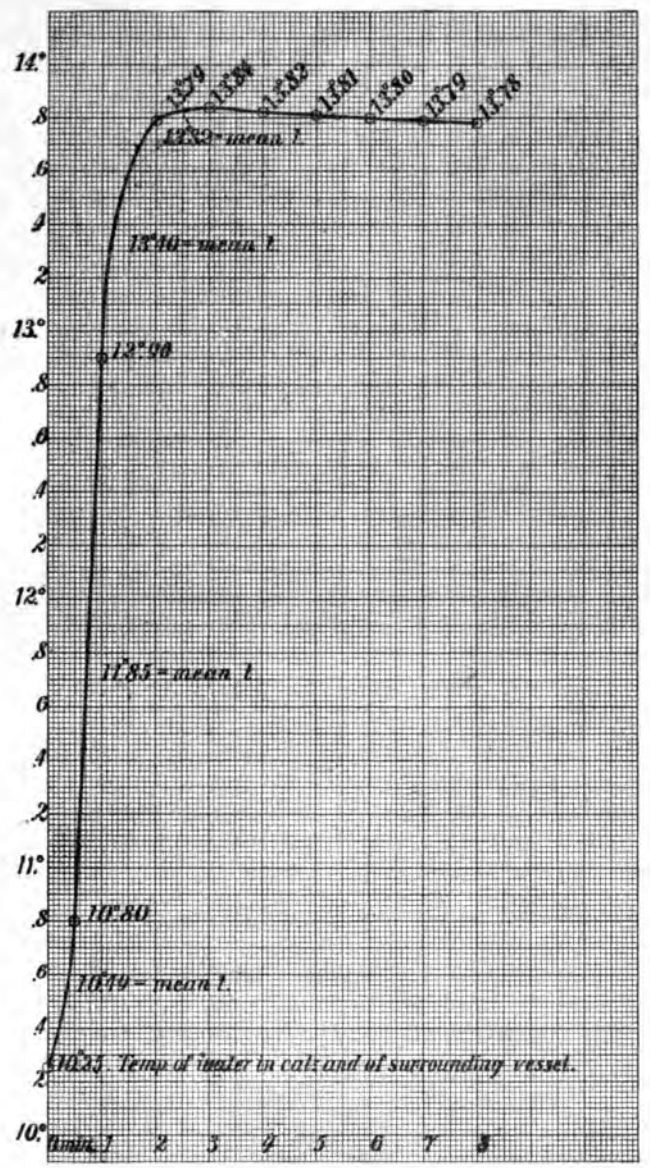
Substance.	Weight in grms.		Specific heat.		Water equivalent
Steel	3590.403	×	.1097[1]	=	393.867
Enamel	20.	×	.2045[2]	=	4.090
Lead	8.2	×	.0314	=	.257
Platinum	22.603	×	.0324	=	.732
Brass	583.22	×	.093	=	54.240
Mercury in ther.	24.41[3]	×	.0333	=	.813
Glass in ther.	7. [3]	×	.1977	=	1.384
Air in bomb[5]	.779	×	.173[4]	=	.135
O @ 25 atmos. in bomb[5]	21.6	×	.158[4]	=	3.415
					458.933

We have taken 459 as the equivalent in water of our calorimeter.

THE WATER-JACKET.

This part of the calorimeter is of prime importance. It surrounds the calorimeter and towards it the *hotter* calorimeter radiates its heat during its rise of temperature after the explosion of the combustible. The water-jacket should be cooler than the calorimeter when the latter has attained its maximum temperature; for, if the water-jacket is then hotter than the calorimeter, the maximum temperature attained by the calorimeter cannot be ascertained (except by tedious subsequent experiments), for the thermometer in the water of the calorimeter will continue to rise after the bomb has given all of its heat to the water of the calorimeter. It is best to have the temperature of the water in the calorimeter, at the moment of the beginning of the combustion of the fuel in the bomb, as nearly as possible the same as the temperature of the water-jacket. This condition is not difficult to obtain.

(1) Determined by Matignon of the College of France.
(2) " " Berthelot and Vieille.
(3) Weights of mercury and of glass immersed in water of calorimeter.
(4) See J. Joly. Proc. R. S. of London. t. 27. p. 218. 1889.
(5) Air and oxygen in bomb are taken at 15°.


14°
13°
12°
11°
10°
1579
1578
1582
1581
1580
1579
1578
12°32 = mean t.
12°10 = mean t.
12°98
11°85 = mean t.
10°80
10°49 = mean t.
10°23 Temp of water in calx and of surrounding vessel.
Time 1 2 3 4 5 6 7 8

PROGRESS OF AN EXPERIMENT AND THE CORRECTION OF THE FINAL TEMPERATURE OF THE CALORIMETER FOR THE LOSS OF ITS HEAT BY RADIATION.

We will suppose that the water in the calorimeter and the water-jacket have the same initial temperature, after the water in the calorimeter has been agitated during several minutes. At the moment of the explosion of the fuel the time is recorded by an assistant, who keeps the agitator in action and calls each half-minute during the progress of the experiment. The observer gives him the temperature at each half-minute which the assistant writes down. When the maximum temperature occurs the observer gives it, and the assistant notes it and the time when it took place. The temperature now begins to fall from the radiation of the hotter calorimeter towards the cooler water-jacket, and the temperature is recorded at the end of each minute till five or six minutes have elapsed. We have now the data from which the maximum temperature of the calorimeter can be corrected for the loss of heat by radiation which took place during the passage of the heat from the bomb into the water.

The successive temperatures as ordinates and the corresponding times as abscissas are plotted in the accompanying curve. This curve is the record of an actual experiment.

The initial temperature of the calorimeter and water-jacket was 10°.25.

During the	1st	half-minute	the	calorimeter	rose	0°.55
" "	2d	"	"	"	"	2°.10
" "	3d	"	"	"	"	0°.7
" "	4th	"	"	"	"	0°.19
" "	5th & 6th	"	"	"	"	0°.05
						3°.59

and reached the maximum temperature of 13°.84 at the end of the third minute. The temperature of the calorimeter now began to fall; and, at the end of the 8th minute, it has fallen, during five minutes, 0°.06, and $\frac{.06}{5}$ = 0°.012, is the loss per minute by radiation of the calorimeter when it had the mean tempera-

ture of $\frac{13.84 + 13.78}{2}$ = 13°.81 (see curve), and differed in temperature from the water-jacket by 13°.81 — 10°.25 = 3°.56.

Newton's law of cooling, viz., that the loss of heat by radiation is as the difference of temperature between that of the hot body and that of its cooler inclosure, may be regarded as exact for the small differences of temperature existing in all experiments with this calorimeter. Applying this law to the successive mean temperatures of the calorimeter, during each half-minute from the beginning of the experiment to the time when the maximum temperature was attained, we get a series of increasing amounts of heat radiated during each half-minute. The summation of these is the correction for loss of heat by radiation.

During the second half-minute (see curve) the gain of heat by the calorimeter was at a uniform rate, as shown by the straight line. The mean temperature of this second half-minute is therefore $\frac{10.8 + 12.9}{2}$ = 11°.85, but during the other half-minutes the gain of heat by the calorimeter is given in curves. To get the mean temperature during these intervals we take from the curves of these intervals the temperature at the beginning of the half-minute, at the ⅛, ¼, ⅜ and end of half-minute and divide their sum by 5.

Making the computation of loss of heat by Newton's law, we have the following results (see curve), $\frac{13.84 + 13.78}{2}$ = 13.81 and 13.81 — 10.25 = 3°.56. With this maximum difference of temperature of 3°.56 between the calorimeter and water-jacket the calorimeter lost 0°.012 per minute and 0°.006 per half-minute.

Loss during	1st	half-minute	3.56 : .006 = 10.49 — 10.25 :	0°.0004
"	" 2d	" "	3.56 : .006 = 11.85 — 10.25 :	0 .0027
"	" 2d	minute	3.56 : .012 = 13.40 — 10.25 :	0 .0106
"	" 3d	"	3.56 : .012 = 13.82 — 1.025 :	0 .0120
				0°.0257

Therefore 0°.0257 has to be added to 13.84 — 10.25, or 3°.59 in order to obtain the real amount of heat which passed from the bomb into the water of the calorimeter. 3.59 + .0257 = 3.616 as the nearest value to thousandths of a degree.

In this experiment, the water in the calorimeter + the equivalent of the calorimeter in water equalled 2681 grams, and 2681 × 3.616 = 9694 calories as the calorific power of the combustible. If this correction of 0°.0257 were not added to the observed difference of 13°.84 — 10°.25, the calorific power of the combustible, so determined, would have been 69 calories less than the real value. In other words, the correction amounts to .71 of one per cent.

The combustion of a coal giving 8000 calories caused the temperature of the calorimeter, having 2859 as number of grams of water + equivalent in water of calorimeter, to rise 2°.787. The radiation correction was + .02. This correction amounts to 57 calories, or .71 of one per cent. These examples give an idea of the value of the correction for radiation. This correction may be taken as generally about .7 of one per cent. of the calorific power of a fuel when applied to experiments made under the conditions just described.

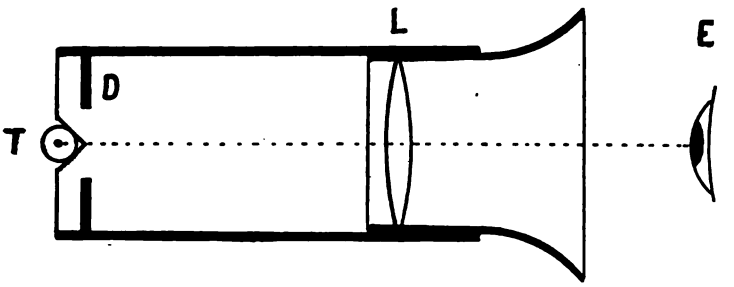
ERRORS MADE IN READING THE THERMOMETER.

An error of 0°.02 may be made in reading the thermometer used in our calorimeter by not having the line of sight at right-angles to the axis of the stem of the thermometer. This error is caused by the refractive action of the glass of the stem. If an observer should read the lower temperature too low by 0°.02 and the higher temperature too high by 0°.02 (which is the likely direction of these errors), he would have made an error of 0°.04. This error is an extreme case, and is given to show what the error might amount to with a careless and unskilful observer. This error of 0°.04 would give 1.5 per cent. in excess of the real calorific power of a coal.

To prevent errors in reading the thermometer, I have devised a simple optical arrangement which not only brings the line of sight at right-angles to the top of the column of mercury, but, also, magnifies the divisions of the thermometer and thus renders more accurate the estimation of the fractions of the smallest divisions on the stem.

In the figure, ⌊ is a lens which forms part of a watchmaker's eye-glass, and is mounted in a tube of such length that by pushing in or pulling out the eye-glass the mercury,

of the thermometer at T, is brought in the focus of distinct vision. The tube has two Vs cut out of its end so that when



the thermometer is in these Vs (as shown in the figure) the stem of the thermometer must be at right-angles to the axis of the tube carrying the lens. To get the line of sight, also, in the axis of the tube and perpendicular to the column of mercury, we have merely to bring the disk of the lens (which is distinctly seen by the eye placed beyond the eye-piece, as at E) to be concentric with the circular opening in the diaphragm, D. In the centre of the opening in this diaphragm is the top of the mercurial column. Thus errors in reading the thermometer are avoided. Such a simple and inexpensive instrument I should think would be of service to engineers in reading thermometers. The diameter of the lens in the instrument used by me is 2.5 cms., and the diameter of the circular opening in the diaphragm is 1 cm. The instrument is shown in the figure of the actual size.

ERRORS CAUSED BY THE MERCURY THERMOMETER ALWAYS GIVING TEMPERATURES WHICH ARE MORE AND MORE IN EXCESS OF THOSE GIVEN BY THE AIR THERMOMETER AS THE TEMPERATURE RISES FROM 0° to 45°.

The correct temperatures of the calorimeter are those given by an air thermometer. Those given by the mercury thermometer are not correct. If the mercury thermometer gives the exact temperature at 0° and at 100° and each degree gives $\frac{1}{100}$ of the apparent expansion of the mercury between 0° and 100°, yet the thermometer, though correct as a mercury thermometer is defined, does not, when compared with the air thermometer,

give correctly the degrees of temperature from readings on the scale between 0° and 100°.

Taking the average + departures from the air thermometer of three of Baudin's thermometers, I projected them in a curve from which we obtained the following comparisons showing the average excess of the readings of the mercurial thermometers when compared with the air thermometer.

Temp. by Air Ther.	Error of Mercury Ther.	Dif. of 4° of Air Ther. in readings of Mercury Ther.
0°	0°.000	
10	+0°.118	14° — 10° = 4°.040
12	+0°.140	16 — 12 = 4°.036
14	+0°.158	18 — 14 = 4°.033
16	+0°.176	20 — 16 = 4°.030
18	+0°.191	22 — 18 = 4°.028
20	+0°.206	24 — 20 = 4°.025
22	+0°.219	26 — 22 = 4°.023
24	+0°.231	28 — 24 = 4°.022
26	+0°.242	30 — 26 = 4°.022
28	+0°.253	
30	+0°.264	

Mercury thermometers give temperatures always in excess of those given by the air thermometer. There is no recorded case of a mercury thermometer giving temperatures lower than those given by the air thermometer. These differences in the temperatures given by the thermometers increase from 0° to 45° then gradually decrease to 100°. Some authors state that this difference may amount to 0°.5 at 45° or 50°. The differences in the readings of the air and mercury thermometers depend on the kind of glass forming the mercury thermometer, on whether the glass is annealed or not, and even on the manner in which the thermometer has been worked under blow-pipe flame. The differences of readings between the two thermometers do not remain constant, and are changed by exposing the mercury thermometer to a high temperature. However, if the thermometer used in the calorimeter is never heated but through the range of the atmospheric temperatures of a laboratory, and the thermometer, as are those made by Baudin, has been thoroughly annealed, the correction by comparison with the air thermometer

will remain sufficiently constant not to introduce errors in computations of the calorific power of fuels. This will be more likely if the thermometer has been made several years before it is compared with the air thermometer.

To ascertain the magnitude of the errors in calorimetry caused by the readings of the mercurial thermometer giving too high temperatures, we must remember that the rise of temperature of the calorimeter is obtained by differences of readings of the thermometer. If the lower and higher readings were affected with the same error the differences would be correct. But this is not so, as is seen in the table we have given.

Suppose that the calorimeter rises 4°, from 16° to 20°. The error in the 16° reading of the mercury thermometer is 0°.176 and in the 20° reading the error is 0°.206, and 0°.206 − 0°.176 = 0°.03 and + 0°.03 equals an excess of 85.74 calories if we have 2858 grams for water in the calorimeter + equivalent of calorimeter in water. In other words we are .75 of one per cent. high in the determination of the calorific power of a combustible giving 2858 × 4 = 11432 calories.

In the case of the combustion of a coal giving 8000 calories the rise of the temperature of the calorimeter, is, say from 16° to 18°.8, or 2°.8. The difference in the errors of the readings 18°.8 and 16° is 0°.197 − 0°.176 = 0°.021. This difference gives 60 calories, or .75 of one per cent. too much in the determination of the calorific power of the coal.

It is evident from this discussion that the determinations of calorific powers of fuels are always too high if the rise of temperature of the calorimeter is measured by a mercury thermometer, the readings of which have not been reduced to those of the air thermometer. In our examples we have taken the errors of the average readings of three of Baudin's thermometers. The errors may be greater or smaller than these according to the thermometer used. With a thermometer made by Geissler, the errors in the readings of the initial and final temperatures of the calorimeter give an error of 2 per cent. in the determination of the calorific power of a fuel. But whatever the magnitude of these errors made by using a mercury thermometer which, as temperature on a mercury thermometer is *defined*, may be exact, but, when compared with the readings of

an air thermometer, may be quite erroneous, they certainly should be known and allowed for in all calorimetric work which purports to be accurate. A formula, $d = \frac{D}{2500} t\ (100-t)$, has been given by Broscha, by which the errors of the mercury thermometer can be computed if we only know the maximum departure of the mercury from the air thermometer. In this formula d = departure of mercury thermometer from air thermometer at t temperature, and D = maximum departure of mercury thermometer from air thermometer, which Broscha places at 50°, instead of at 45° which latter is really the temperature at which the maximum difference exists.

Computing by this formula the temperatures on a Baudin thermometer whose maximum departure from the air thermometer is 0°.34 at 45°, we obtain for 16° and 20°, 16°.183 and 20.217, giving a difference of 4°.034. The real readings of the Baudin thermometer, reduced to those of the air thermometer, are 16°.176 and 20°.206, giving a difference of 4°.030. The difference of the differences amounting to only 0°.004.

ERRORS ARISING FROM A PORTION OF THE MERCURY IN THE STEM OF THE THERMOMETER BEING ABOVE THE WATER IN THE CALORIMETER.

The mercury in the stem which is above the level of the water in the calorimeter, at the initial temperature, is not heated when the mercury in the bulb and stem of the thermometer below the surface of the water is heated; therefore the thermometer must read a lower temperature than that which is the real temperature of the calorimeter.

The correction for this error is found as follows:

Let t = the temperature of the air, which we will suppose is the same as the initial temperature of the water in calorimeter.

T = final temperature of water in the calorimeter.

n = number of degrees in the stem of the thermometer above the water in the calorimeter.

Then from the known coefficient of apparent expansion of mercury in glass, viz., $\frac{1}{6500}$, the correction to be applied to the reading is $+ \frac{n(T-t)}{6500} = 2\frac{1}{10}$ of a degree if $n = 6$ and $T - t = 4$.

This correction is seen to be small. It is necessarily so in the thermometer used, because $T - t$ never exceeds 4° and the scale of the thermometer does not exceed 10°; therefore n does not exceed 6 units or, at most, 7 units. An error of $\frac{1}{2}\frac{1}{10}$ of a degree will give a deficiency of .15 of one per cent. in the determination of the calorific power of a coal giving 8000 calories.

ERRORS RESULTING FROM PLACING IN THE CALORIMETER MEASURED, INSTEAD OF WEIGHED, WATER AND FROM TAKING UNITY AS THE SPECIFIC HEAT OF WATER AT ALL TEMPERATURES BETWEEN 0° AND 30°.[1]

Berthelot, in his *Traité Pratique de Calorimétrie Chimique*, says: "The calorie varies but by an extremely small quantity when we use water at a higher temperature than 0°, say at 15° or 20°; indeed, it is usual to regard as constant the quantity of heat absorbed for each degree comprised in that range of temperature, which fact simplifies the calculations. We diminish the small errors thus made by using a cubic centimetre of water instead of a gramme; the weight of a cubic centimetre of water diminishing as the temperature rises above 4°, while the specific heat gradually *increases*. By using this method (of getting the weight of water in a calorimeter) the error made in the computation is less than the experimental errors." This statement is erroneous. The specific heat of water at 30° is one per cent. *less* than at 5°, and 1 per cent. is not "an extremely small quantity." Also the specific heat of water does not "gradually increase" as its temperature rises from 4° to 20°, but it *decreases*. So the balance of errors which Berthelot assumes cannot take place.

Rowland[2] has conclusively shown, in his experiments on the mechanical equivalent of heat, that the specific heat of water *decreases* as the temperature rises from 5°, reaching a mini-

[1] In this discussion we suppose that the temperatures given by the thermometer are correct. That is, that the readings of the thermometer are reduced to those given by the air thermometer.

[2] On the Mechanical Equivalent of Heat, by Henry A. Rowland. Proc. of the Am. Acad. of Arts and Sciences, Boston, 1880. See also A. Bartoli and E. Stracciati, Bull. mens. dell' Acc. Gioenia, April, 1891, who have confirmed Rowland's results.

mum value at 30°, when the specific heat is one per cent. less than 5°. The following table is computed from Rowland's determinations of the mechanical equivalent of heat for various temperatures of water:

Temperature.	Specific Heat of Water.
5°	1.00000
10°	.99697
15°	.99418
20°	.99209
25°	.99069
30°	.99022

To determine the magnitude of the error caused by using measured, instead of weighed, water in the calorimeter, we will assume that a graduated vessel of glass holds 2400 cubic centimetres of water at 4°. At 15° the capacity of the glass vessel has expanded to 2400.9 cubic centimetres, and 2400.9 cubic centimeters of water at 15° will weigh 2398.84 grammes. Now the specific heat of water at 15° is .99418, and 2398.8 × .99418 = 2384.8. So that, if we assume that the decreased weight of measured water is corrected by its *increased* specific heat, we have made an error of 2400 — 2384.8 = 15.2 calories for 1° rise in the temperature of the water in the calorimeter.

The water in our experiment in the determination of 8000 calories as the calorific power of a coal rose from 15° to 17.8. Taking .9935 as the mean specific heat of water between 15° and 17°.8 we have 2398.8 × .9935 = 2383 and 2400 — 2383 = 17, and 17 × 2.8 = 47.5. That is, we have an error of 47.5 calories or .59 of one per cent. in the determination of the calorific power of the coal.

The above example is, however, an extreme case, for the graduated glass vessel may as well be gauged to hold 2400 grammes at 15°; that is, the weight of water in the calorimeter is correct. Now, the error in taking 1.00000, instead of .9935, as the specific heat of water in our experiment on the coal will be 2400 — (2400 × .9935) = 16, and 16 × 2.8 = 44.8 calories, and we have a deficiency in the determination of the calorific power of the coal of .56 of one per cent.

That the specific heat of water decreases with the rise of temperature from 5° to 30° cannot be doubted, and it is for

physicists and engineers to take it into consideration in their computations. The difference of the result computed by taking the specific heat of water as unity at all temperatures and by taking the correct specific heat may generally, I suppose, be neglected by engineers, but not by physicists and chemists, for ½ of a per cent. is not to be neglected in the precise work required in determining, as scientific data, the calorific powers of substances of definite chemical composition.

ERROR CAUSED BY EVAPORATION OF WATER IN THE CALORIMETER.

The following experiment shows the magnitude of the correction for evaporation. The temperature of the air and of the 2400 grams of water in the calorimeter was 16°. The barometer stood at 763.5. The air was quite dry, the relative humidity being only 41. The rate of evaporation of the water was 0.008 gram per minute. If an experiment lasts ten minutes the water in that time has diminished 0.08 gram, which equals a deficiency in the determination of the calorific power of a coal of $0.08 \times 2.8 = .224$ of a calorie, or, of .0027 of one per cent.; a quantity too minute to enter into the computation.

MECHANICAL INTEGRATORS.

BY PROF. J. BURKITT WEBB.

AMSLER'S PLANIMETER.

(*Continued.*)

PLUS AND MINUS AREAS.

When all the infinitesimal elements composing an area have the same sign, the area has of course that sign; and when some of them are plus and some minus (see the Table of Signs, page 40), the predominating sign belongs to the whole area. Usually it is only the numerical value of an area that is wanted, in which case no attention is paid to the sign, should it be minus. In general, however, it is better to use the instrument so that its results are plus, *i. e.*, so that R_2 is greater than R_1, unless it should prove troublesome to do so on account of the circumference of the Zero-Circle passing more or less centrally through the areas.

The signs of the elements of an area may easily be determined by inspection in accordance with the Table of Signs, as has been shown, but the sign of the whole area can in many cases be found only by an actual integration, mechanical or otherwise, the plus and minus elements being too nearly balanced. It must, therefore, be kept distinctly in mind that the question of plus and minus areas is in general another thing from that of plus and minus elements.

There is, however, quite independent of the planimeter, a mathematical method of determining the sign of an area. The boundary of every area must be passed over in one of two directions, and, the direction having been chosen, that of passing over a part of every element is fixed, and therefore the proper direction for making the circuit of every element, and therefore

n, as will be seen, is known. The rule for determining

n is simply that in going round the boundary an area

lying on the right hand is plus and one on the left minus, and it will be found that this rule applies equally to the elements and to the various portions of the whole area. The boundary may indeed be supposed to be a fence, ready-made, with the posts fast to the plus side of it, capable of being set up in any shape, even such as the numeral 8, the crossing of the fence by itself leading to no difficulties (see Fig. 32). The effect and elegance of this mathematical view of a boundary will appear in considering various Forms of Area.

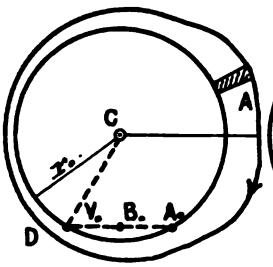


FIGURE 27.

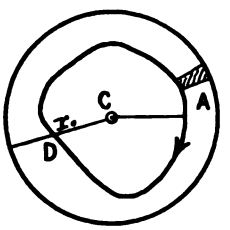


FIGURE 28.

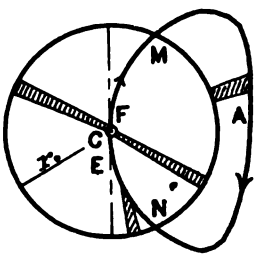


FIGURE 29.

FORMS OF AREA.

A variety of areas will now be examined having boundaries of different characters, the circuit of which is supposed to be made by the Stylus in the direction indicated by the arrow-heads, and what will be said is applicable also to algebraic integration. The planimeter indicated in Fig. 27, by the dotted lines $C\ V_0\ B_0\ A_0$ only, will be supposed to have $c = 2b = a = r_0$, and to be an ideal instrument, as has been in some previous cases virtually assumed, so constructed, or rather conceived of, as to allow A to approach within an infinitesimal distance of C and β to increase without limit.

Fig. 27 shows an area bounded by a curve lying entirely outside of the o-Circle. The differential areas are all as shown and are plus under Case I. of the table, and the area of the curve evidently is, n being equal to unity,

$$A = A_0 + R$$

R being the area outside of the o-Circle only and being plus.

Fig. 28 shows an area entirely within the o-Circle. Here all the elements are as shown, and minus under Case III., consequently we have the area

$$A = A_0 + R$$

R being the area between the o-Circle and curve, and being now minus, as all its elements are.

Both of these areas belong to the same normal form, characterized by $n = 1$, and it should be noted that, inasmuch as the centre C lies within it, the second area virtually includes the o-Circle, as the first actually does, although, apparently, the area lies within the circle.

By an elegant mathematical device both of these areas may be changed to another normal form, characterized by $n = o$ and having the centre of the o-Circle, and therefore virtually the circle, outside. This change removes A_0 from the formula and leaves, therefore, $A = R$.

To effect this change it is only necessary to pierce the area, Fig. 27 or 28, with an infinitesimal circular hole concentric with C, and slit open the irregular annulus thus formed along any line, as CA. This does not alter the area, though it changes the boundary in such a way that C is no longer within it. If now the Stylus be made to follow the curve from any point, as D, up and around until the slit is reached, then along the upper side of the same to the infinitesmal hole, then around that and back again by the lower side of the slit to the original curve and down and around this to the starting-point, the reading R will give the area without the addition of A_0.

The reason that the Zero-Circle has thus disappeared from the formula is that, during the revolution of 360° in the negative direction around the infinitesimal hole at the centre, 360° of dA_0s has been included in the integration, each dA_0 being plus under Case IV., so that the Zero-Circle has been added by the integration itself. Of course an actual planimeter might not use entirely, so that the Stylus could follow the central

circle, but one might be made to allow of this, and thus make the device capable of a practical application.

Fig. 29 shows an area, like Fig. 6, partly within and partly without the Zero-Circle, but here the boundary has been intentionally drawn *through* C, according to the ordinary way of stating the fact. In reality the line must lie one side or the other of C, and the same result follows from the exclusion of C as before, namely:

When the line passes to the left of C,

$$A = A_0 + R,$$

and when it passes to the right,

$$A = R.$$

In the figure C is, as usual, the centre, while E and F are the points where the boundary meets an infinitesimal circle. It is not necessary to have this circle, but it simplifies the conception to introduce it and to suppose that the dotted tangent to the boundary cuts it into two semi-circles, EF and FE, either of which may be considered to be a part of the boundary.

In the first case, start at A, and go to N, integrating plus elements under Case I.; then from N to E, still along the boundary, around the left-hand differential semi-circle EF from E to F, and along the boundary again from F to M, with elements all minus under Case III.; and finally finish along the boundary from M to A, with plus elements. These minus elements subtracted from the Zero-Circle, leave that portion of it which is inside the boundary, so that the first of the above formulæ is evidently correct for this case.

If, instead of passing around to the left from E to F, the right-hand semi-circle be taken from E to F, then, instead of the 180° of minus elements under Case III., we shall have plus elements under Case IV. Evidently, then, the omission of the half-circle of minus elements and the introduction of the half-circle of plus elements introduces the o-Circle into the Reading itself, so that the second of the above formulæ is applicable.

The shaded elementary areas in Fig. 29 illustrate the cases, thus; that at A is plus, that at N minus, while of those which extend from the 0-Circle to the centre, that at the left is minus and that at the right plus.

In Fig. 30 a further proof of the formula for A, viz.:

$$A = R,$$

is as follows: When C lies outside the area,

$$MANDM = MANCM - MDNCM;$$

but $$MANCM = MZNCM + MANZM,$$

and $$MDNCM = MZNCM - MZNDM.$$

Subtracting, the sector of the Zero-Circle disappears, and

$$MANDM = MANZM + MZNDM.$$

The first of these areas is plus under Case I. and the second under Case IV., so that the instrument must register their sum, and no addition of the Zero-Circle be necessary.

Fig. 31 shows an area similar in character and illustrating cases I., II., and IV. of the Table of Signs of the Elements.

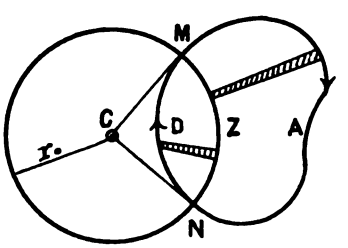


FIGURE 30.

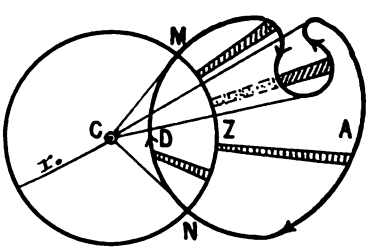


FIGURE 31.

CROSSED BOUNDARIES.

A full discussion of the forms assumed by areas leads to the consideration of those whose boundaries cross themselves one or more times, as seen in Figures 32 to 35.

Considering Figure 32, without at first any reference to the planimeter, it is seen that the partial area C_1 is *plus*, inasmuch as it lies on the right-hand side of the boundary, or on the post the fence. The other portion C_2 lies on the left-hand, le of the fence, and is therefore *minus*. To complete

the notation, area neither plus nor minus, as at C, may be called *neutral.* Now it must be plain that, if C_2 is numerically equal to C_1, the whole area equals zero.

The same result will be obtained if the area be found by integrating according to any system of co-ordinates. Thus suppose that, with the Needle-Point at C, the Stylus makes the circuit in the direction of the arrow-head; the result must be zero, as the second loop will be minus. With the Needle-Point at C_1 or C_2 the same result is obtained, the area A_0, however, coming into the formula already given, viz.;

$$A = nA_0 + R$$

with $n = 1$ for C_1 and $n = -1$ for C_2, because in the latter case θ finishes with its initial value minus 2π. The formulae for the three cases will therefore be

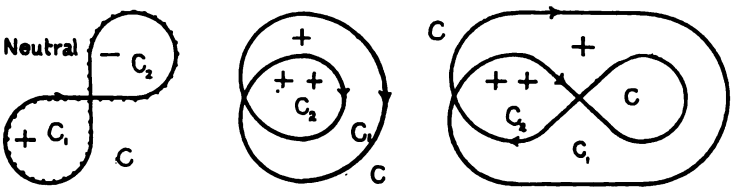
$$A = R$$
$$A = A_0 + R$$
$$A = -A_0 + R$$

Of course an area can be made of apparently the same shape as this figure without the fence crossing itself, but the C_2 portion would then be on the post side of the fence — an entirely different case. There would then be a differential passage between the two corners at the middle of the figure eight.

To form a clear idea of the essential continuity of this surface with the crossed boundary, imagine a thin material film stretched upon the latter, like a soap film upon a bent and crossed wire; then an insect placed at C_1 might crawl to C_2, but it would arrive there on the under side of the film, because at the middle of the figure it would crawl over a differential warped surface with a twist of 180°. To get from C_1 to C_2 requires the crossing of the fence twice from the post side over. One such crossing from inside to outside, which will be called a minus or negative crossing, leads from plus to neutral area, while the second crossing leads from neutral into minus area. These crossings may be made separately anywhere, or

they may both be made at once at the middle of the figure. A plus area may be regarded as a part of the surface which has been included by the fence, while a minus one has, on the contrary, been expressly excluded thereby.

FIGURE 32. FIGURE 33. FIGURE 34.



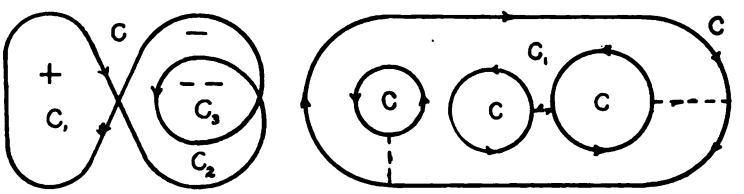


FIGURE 35. FIGURE 36.

Figure 33 shows an area having both a singly- and a doubly-included portion, the latter having been fenced in twice, so that to reach it from neutral area requires two plus crossings. An integration of such an area gives a result in which the doubly-included part is counted twice, and a material film stretched on the boundary would also be double throughout C_2.

In using the planimeter on this figure the Needle-Point may again be put in three places, C, C_1 and C_2, with the result that the formula for the area will have n equal to 0, 1 and 2, respectively, thus;

$$A = R$$
$$A = A_0 + R$$
$$A = 2A_0 + R$$

In the latter case it will be seen that the final value of θ is 4π greater than its initial value.

Figure 34 shows a combination of singly- and doubly-included with an included-excluded, and therefore neutral, area.

The four positions for the Needle-Point give n equal to 0, 1 and 2, according to the subscripts of C.

Figure 35 shows an included, excluded and doubly-excluded area. Also, n equals 0, 1, -1 and -2, respectively, for the four Needle-Point positions shown.

In these figures it will be seen that a plus fence crossing raises the order of an area, that is, changes it from minus to neutral, from neutral to plus, from plus to double-plus, etc., while a minus crossing lowers it.

DISCONTINUOUS BOUNDARIES.

An area is sometimes a part of the surface lying between two or more separate curves, in which case, inasmuch as the area is a single concept, it is proper to unite the curves in a conception of a single boundary, though a discontinuous one. This is the reverse of the cases in which the boundary was continuous and the area separated into parts by the crossing thereof.

Figure 36 shows such an area lying between an exterior closed curve and three interior ones. Other more complicated forms might be shown, but this will suffice to illustrate a method of treating such cases. Imagine the area cut out of a piece of paper and the three holes to be cut out of it. Now by cutting the three slits, represented by the dotted lines, from the outside to the holes, the boundary will be made continuous without altering the area; the Stylus may then be passed around it with the Needle-Point in any suitable place. For C, n equals zero, and for C_1 it is unity. It is evident that, in going over the boundary, the Stylus goes over the two sides of a cut in opposite directions, so that they have no effect upon the Reading.

Of course the area can also be obtained by measuring the holes separately and subtracting their sum from the large area, but this is, theoretically, not so elegant a method.

All the above laws as to areas hold also for algebraic integration and for calculations made by the Latitude and Departure method of Land-Surveying.

CAPACITY OF THE INSTRUMENT.

It has been suggested already that a lengthening-bar might be used to increase the value of c and thus extend the capacity of the instrument; for any particular value of c, however, the areas measurable by the planimeter are limited in a manner to be explained.

An instrument only which can be fully opened and closed will be considered; the capacity of an actual planimeter, with a limited motion of the hinge, is evidently less. Figures 37 and 38 are drawn, the former for excluded and the latter for included C; in the latter the right-hand half has c greater, and the left-hand, c less than a, while in the former this distinction is made

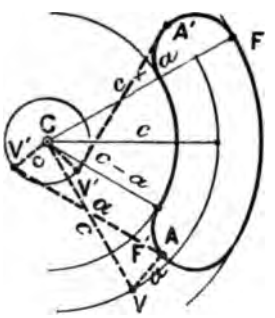


FIGURE 37.

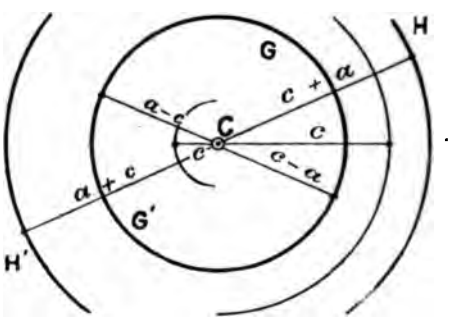


FIGURE 38.

by showing two planimeter positions with c less than a. In these figures c is either four times a, or a four times c.

Case I. $c > a$.

When C lies within the boundary the greatest measurable area is evidently that of a circle described with the instrument open, and therefore with the radius $c + a$, and the smallest is described with the instrument closed and the radius $c - a$.

With C excluded, the greatest area is that of a curved strip lying between the same two circles, so that no circle larger than one with radius a can be measured. The smallest area is zero.

The capacity of such an instrument is not only limited, therefore, by the radius $c + a$, but it may be discontinuous; for

it will measure circles only whose radii lie between o and a, or between $c - a$ and $c + a$, so that if

$$c - a > a$$

that is, $$c > 2a$$

the series is *discontinuous*, and circles cannot be measured whose radii lie between a and $c - a$.

It is to be noted that the adjustable planimeter, shown in Figure 2, has one setting with a equal to two-and-a-half inches only, while c is over six; for this setting it is therefore not possible to measure circles whose diameters lie between five inches and seven-and-a-half inches.

Case II. $c < a$.

For included C, by exchanging the values of a and c, the same actual limits are obtained as in the former case; that is, the measurable circles lie between $a - c$ and $a + c$. For excluded C, also, the actual limits are the same, being expressed, however, as from zero to c.

The same discontinuity therefore occurs for

$$a > 2c$$

as for $$c > 2a.$$

It may be remarked in Figure 37 that, in Case I. the upper semi-circular end of the curved strip is described with the Radius-Bar stationary, but that the lower end is gone over in the different manner indicated; in Case II., however, the instrument is shown at both ends with the Radius-Bar in motion. Any other way of making the circuit would not return β to its initial value.

PECULIAR CASE.

From what has been said it appears that one-half of a circle of radius a may be described with the Radius-Bar stationary, but that the other half may not be so gone over. It will be interesting to notice the effect of making the complete circuit with V at the centre of the circle. The planimeter, of course, must be capable of unrestricted motion of the Hinge.

Figure 39 shows this case of an area concentric with V, when c is greater than a, and it can be seen that the planimeter when so handled, will not give the correct value of A. Thus in the figure the wheel remains stationary, so that R is zero, while A describes the circle whose area is πa^2. The area A then is not given by the formula

$$A = nA_0 + R$$

in which n is zero, as previously explained.

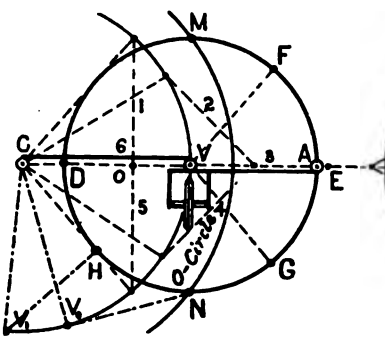


FIGURE 39.

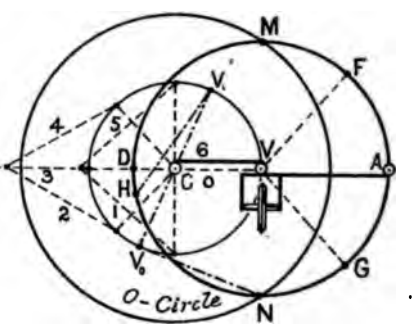


FIGURE 40.

It is to be remarked that the instrument fails to measure the area not only when the Stylus goes completely around the circle, but also that it fails to measure the area between the Zero-Circle and the curve when the Stylus goes from M to N, or from F to G. In these three cases the Stylus finishes at its initial distance from C, which shows that it is not enough that it shall do so but that the true restriction is that β shall *return* to its initial value. If now β be returned to its first value, A generates negative area neutralizing the positive and leaving no area described, so that as $n = o$ the formula remains true.

The limited motion of the Hinge in the ordinary instrument prevents β from acquiring its initial value without returning to it, but it may let r do so for β equal to minus that value.

This leads to an appreciation of the fact that β is only an adjusting angle for the instrument, and that in the measurement of an area the planimeter should be revolved as a whole about C.

To measure this area C is best located inside of it, although the area may be correctly measured with C outside by following the lower semi-circle in the manner already shown in Figure 37. Figure 39 shows the manner of making the circuit more in detail. Commencing at D the Stylus passes through M to A with V stationary, then through N and H back to D, while V swings out to V_0 and V_1 and back again to V, so that θ as well as β returns to its initial value.

Another way to obtain the correct area is as follows: Let the Stylus make the circuit D M A N D with V stationary, and then follow the diameter from D to A through V and back again to D, while the Measuring-Bar takes successively the positions 0 1 2 3 4 5 6, thus returning β, as well as θ, to its initial value. The result thus obtained is somewhat paradoxical, inasmuch as the area of the circle has been measured by passing the Stylus twice over its diameter.

Fig. 40 shows the same for c less than a, with some differences. As the Stylus follows the path A N H D, V swings out through V_0 to V_1, but instead of then returning through V_0 to V it makes the complete circuit around C to V, thus increasing θ by one revolution, so that n, in the formula for the area, equals unity. Furthermore, after the Stylus has made the complete circuit, θ is increased to 2π and β returned to its initial value by passing the Stylus from D to E and back again, which is not the diameter of the circle, the numerals indicating the successive positions of the Measuring-Bar, as before.

CURVILINEAR CO-ORDINATE SYSTEM.

The instrument embodies also a system of co-ordinates entirely curvilinear, to which the above considerations naturally lead, and which will be useful in the discussion of the Polar Tractrix; thus all positions of the Stylus, for given values of a, b, and c, may be referred to the two angles γ and β as co-ordinates, γ being the angle which the Radius-Bar makes with OX, and β, that between its prolongation and the Measuring-Bar.

This system, with the division of the plane into elements, is shown in Figure 41 for $b = a$. By using, instead of γ,

$$r_0\gamma = \sqrt{c^2 - b^2} \cdot \gamma$$

this co-ordinate may be laid off from O along the Zero-Circle as an Axis of Ordinates, that is to say, r_0 may be considered as the unit for these measurements.

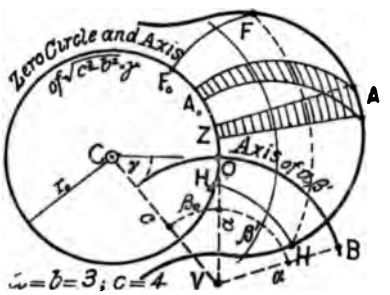


FIGURE 41.

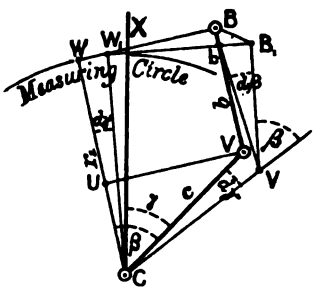


FIGURE 42.

The Axis of Abscissas is then a circle described by the Stylus at B through O, with V stationary, and the plane is cut up into elements by a series of such circles, drawn for consecutive values of γ, intersected with circles drawn about C for consecutive values of β. It may here be better to employ

$$\beta' = \beta_0 - \beta$$

in place of β, it being measured as shown in the Figure, $a\beta'$ can then be laid off from O along the Axis of Abscissas; however, in the Polar Tractrix β and β_0 will still be used.

In the Figure, A_0A is an elementary strip of this System, while Z A is a strip of the other system. A comparison shows that the smaller elements into which the concentric circles cut the strips are the same in both systems, so that a straight strip may be transformed into a curved one simply by sliding these smaller elements upon each other. In this System also the wheel measures the area of a strip as the Stylus passes over the end of it, and, with β returning to its initial value, it measures the area between the Zero-Circle and any curve, and between two arcs of circles about V connecting the curve and circle.

POLAR TRACTRIX.

The Zero-Circle is the circle traced by the Stylus while the Measuring-Wheel follows another circle without revolving. Whether or not this is the only path in which the Stylus may be moved, without causing the wheel to revolve, has not been considered. The problem may therefore be stated in a more general way, as follows:

PROBLEM.—*Required the path of the Stylus of Amsler's Planimeter when the Measuring-Wheel does not revolve.*

GENERAL ANALYSIS.

A consideration of the problem shows that the real question is as to the path of the wheel itself when it does not revolve. In fact, when the wheel follows such a path, a whole family of curves may be traced by the Stylus if all possible values are given to the length a of the Measuring-Bar. Furthermore, as the position of the wheel in its own plane does not affect its motion, the problem may be simplified by supposing the wheel to be located at B, where VA pierces its plane. With the wheel in this normal position and the Stylus removed, the planimeter is reduced to a simple form, in which the wheel may be supposed to act both as Measuring-Wheel and Stylus, so that a equals b.

In order that the Measuring-Wheel at B may not revolve, the necessary and sufficient condition is that it shall move always in the line VB, that is, in the direction of its axis. The wheel is therefore, nothing more than a heavy body dragged along after V, and the curve which it describes is a tractrix, which, as V follows a circle, may be called a Polar Tractrix.

This curve might be traced on the drawing-board by such a planimeter, but with a necessarily slow motion, in order that the curve may not be disturbed by centrifugal force. It is, however, better to mount a printing-wheel or a drawing-pen at B, with its plane passing exactly through V, or a conical metallic point may be used with prepared paper.

MATHEMATICAL ANALYSIS.

FUNDAMENTAL PROBLEM.—*Required the path of the point* B, *moving always in a line passing through* V.

Solution.—The path of B, Fig. 42, is a function of β and γ, which are independent of each other. If now, with β constant, the increment $d\gamma$ be added to γ, the whole quadrilateral CVBW will be revolved about C, without change of shape, into the consecutive position $CV_1B_1W_1$, thus moving B out of the line VB a distance $bB_1 = WW_1 = r_1 d\gamma$.

With γ constant, β must now be increased by such a differential (here a minus one) as will bring B back to the line. This gives

$$r_1 d\gamma = b\, d\beta.$$

But $$r_1 = c \sec\beta + b$$

and $$b = -c \sec\beta_0$$

(remembering that $\sin$, $\cos$, $\tan$, $\cot$, $\sec$, and cosec stand for sin, cos, tan, cot, sec, and cosec) at least when b is less than c, which is the case that will now be considered. Substituting these values, there results

$$d\gamma = \frac{-\sec\beta_0}{\sec\beta - \sec\beta_0}\, d\beta$$

which is the *Differential Equation of the Polar Tractrix* for the case, at least, which has a real angle β_0.

To integrate this expression, the half-angles may be introduced in a symmetrical form, thus:

$$\beta = \tfrac{1}{2}(\beta+\beta_0) + \tfrac{1}{2}(\beta-\beta_0)$$

and $$\beta_0 = \tfrac{1}{2}(\beta+\beta_0) - \tfrac{1}{2}(\beta-\beta_0).$$

Putting $$\sin_1 = \sin\tfrac{1}{2}(\beta-\beta_0)$$

and $$\sin_2 = \sin\tfrac{1}{2}(\beta+\beta_0),$$

with the same subscripts for the cosines of these half-angles,

$$\sec\beta = \sec_1\sec_2 - \sin_1\sin_2$$

and $$\sec\beta_0 = \sec_1\sec_2 + \sin_1\sin_2$$

so that $$\sec\beta - \sec\beta_0 = -2\sin_1\sin_2.$$

The differential equation therefore becomes, after dividing both

sides by $-\nabla\beta_0$ and multiplying by $\Lambda\beta_0 = \Lambda_2\nabla_1 - \Lambda_1$

$$-\lrcorner\beta_0 \cdot d\gamma = \frac{\Lambda_1\nabla_2 \frac{1}{2}d\beta - \Lambda_2\nabla_1 \frac{1}{2}d\beta}{\Lambda_1\Lambda_2}$$

which is in the form of the differential of the natural logarit. of a fraction, as may be seen by comparing it with

$$d\,lg\frac{y}{x} = \frac{x\,dy - y\,dx}{x^2} \div \frac{y}{x} = \frac{x\,dy - y\,dx}{xy}.$$

Therefore $$-\lrcorner\beta_0 \cdot \gamma = lg\frac{\Lambda\frac{1}{2}(\beta+\beta_0)}{\Lambda\frac{1}{2}(\beta-\beta_0)} + lg\ const.$$

Suppose now that for $\gamma = o$, β also is o, then

$$-\lrcorner\beta_0 \cdot o = lg\frac{\Lambda\frac{1}{2}\beta_0}{\Lambda\frac{1}{2}(-\beta_0)} \cdot const. = lg(-1 \cdot const.).$$

But the number whose logarithm is zero is 1, therefore

$$-1 \cdot const. = 1$$

or $$const. = -1.$$

This gives $$-\lrcorner\beta_0 \cdot \gamma = lg\frac{\Lambda\frac{1}{2}(\beta_0+\beta)}{\Lambda\frac{1}{2}(\beta_0-\beta)}.$$

Suppose again that for $\gamma = o$, $\beta = \frac{1}{2}\pi$;

then $$-\lrcorner\beta_0 \cdot o = lg\frac{\Lambda\frac{1}{2}(\pi+\beta_0)}{\Lambda\frac{1}{2}(\pi-\beta_0)} \cdot const. = lg\ 1 \cdot const.$$

therefore $$const. = 1.$$

Both of these cases may then be expressed by

$$-\lrcorner\beta_0 \cdot \gamma = lg \pm\frac{\Lambda\frac{1}{2}(\beta_0+\beta)}{\Lambda\frac{1}{2}(\beta_0-\beta)}.$$

which is the *Natural-logarithmic Equation of the Polar Tractrix.* The plus sign refers to a curve lying outside of the Zero-Circle and the minus sign to one within it.

The equation may be put in the form

$$e^{-\lrcorner\beta_0 \cdot \gamma} = \pm\frac{\Lambda\frac{1}{2}(\beta_0+\beta)}{\Lambda\frac{1}{2}(\beta_0-\beta)}$$

which is the *Exponential Equation of the Polar Tractrix.* These are *equations of pure form*, containing no parameter of *size*; they therefore include all sizes in one equation. It should be noticed that $-\lrcorner\beta$ is a plus quantity in the figure.

CONSTRUCTION OF THE EQUATION.

As has been suggested, an instrument might be made to construct its own Polar Tractrix, or the curve can be drawn geometrically as follows: Mark the length, $VB = b$, of the Measuring-Bar upon the straight edge of a strip of thick paper and place the edge so that V and B coincide with V_0 and B_0, Fig. 43. Then place the pencil against the edge at the cusp B_0 and rule a small portion of the curve. Now, without raising the pencil, advance V along the V-circle, letting the edge slide against the pencil until B is a little past it, then rule another piece of the curve, moving the pencil past B again. Proceed in this way until enough of the curve is drawn, taking care to rule short lengths only where the curvature is great. This process depends, of course, upon the fact that VB is always a tangent to the curve at B.

A more accurate way of constructing the curve is to draw it through a series of points obtained from the Equation of the Curve, and by putting this in a different form and adapting it to common logarithms, the process is facilitated. Thus, the equation may be written:

$$-.4343 \sqcup \beta_0 \cdot \gamma = lg_{10} \frac{Chord\ (\beta_0 + \beta)}{Chord\ (\beta_0 - \beta)} = lg_{10} \frac{B_n B'_z}{B_n B_z}$$

inasmuch as the common logarithm equals .4343 times the natural logarithm and the ratio of two chords in any circle is the same as that of the sines of half the arcs which they subtend. It will be seen also that the formula applies to both inner and outer branches without change of sign, and that $-\sqrt{(c^2 - b^2)}$ divided by b, is the value of the tangent of β_0.

Figure 43 shows a number of suitably chosen points on the semicircle $B_0 B_z\ B'_0$, from which chords, as $B_n B'_z$ and $B_n B_z$, may be drawn to the two intersections with the Zero-Circle. These chords have their lengths set down in the second and third columns below, opposite the numbers of the points, while the fourth column contains the difference of their logarithms.

As the difference of the logarithms equals γ multiplied by a constant factor, a circle might be described with this factor as radius and the difference laid off on its circumference. For $c = 5$ and $b = 3$, the tangent of β_0 is minus four-thirds, and therefore the factor is .4343 times four-thirds, which equals .579. It will, however, make a neater and more accurate drawing to use the V-circle instead. The radius of this is 5, and a fifth column is therefore added to the table containing the values of five times γ, which are obtained from the fourth column by multiplying by five and dividing by .579.

TABLE OF β AND γ CO-ORDINATES FOR FIGURE 43.

Points.	*Chord* $B_nB'_z$	*Chord* B_nB	*Dif. of Logs.*	5 *times* γ.
0	5.40	5.40	0.	0.
1	5.92	4.38	.1308	1.129
2	6.00	3.82	.1961	1.693
3	5.98	3.12	.2825	2.440
4	5.84	2.39	.3880	3.350
5	5.70	1.91	.4749	4.100
5	5.56	1.53	.5604	4.838
6	5.36	1.01	.7249	6.258
7	5.14	.59	.9401	8.117
8	5.00	.30	1.2219	10.549
9	4.89	.12	1.6104	13.903
10	4.83	.03	2.1989	18.900
∞	4.81	.00	∞	∞
8	4.79	.03	2.1989	18.900
7	4.75	.10	1.6767	14.475
6	4.70	.19	1.3933	12.030
5	4.62	.34	1.1331	9.782
4	4.44	.61	.8621	7.443
3	4.16	1.00	.6191	5.345
2	3.91	1.35	.4619	3.988
1	3.57	1.77	.3047	2.631
0	2.70	2.70	0.	0.

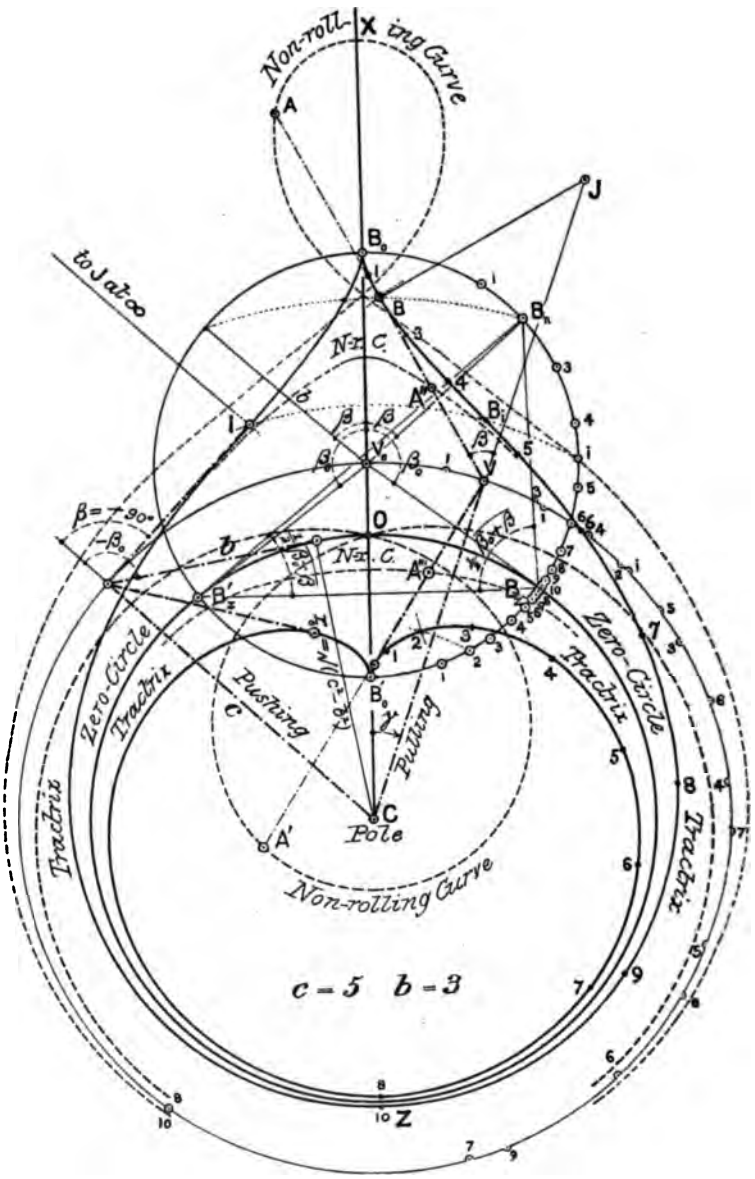


FIGURE 43. POLAR TRACTRIX.

To lay out the curve by means of this table the distances in the last column are laid out from V_0 both ways around the V-circle and numbered in order. With these points as centers and the radius $VB = V_0B_0 = b$, arcs are described cutting other arcs previously drawn, with C as a center, through the corresponding points on the B-circle. If these intersections are too acute near the cusps the values of β, obtained from the B-circle, may also be used. In this way the Tractrix, Fig. 43, is laid out and the planimeter is indicated in pushing and pulling positions for both outer and inner curves.

The outer and inner curves, described by the Stylus, A or A′, when a equals b, are also shown; also portions of those by A″ or A‴, for a equals one-and-a-half. The Table is made for only a half turn of the spiral, inasmuch as the rest of the curve lies too close to the Zero-Circle to be easily drawn separate from it.

DISCUSSION OF THE CURVE.

The curve may be conceived as continuously traced by B in the following manner: Let B be placed on the Zero-Circle with γ equal to minus infinity and β equal to minus β_0, and let it be pushed ahead of V by revolving the Radius-Bar around C in the plus direction. At first B will follow the circle, but, as it is impossible, either actually or theoretically, to give to β_0 the value corresponding to

$$\angle \beta_0 = -b \div c$$

with sufficient exactness to make it impossible for B to leave this circle, B will, after an infinite number of turns when γ has acquired a finite value, gradually leave the circular path, either on the inside or outside, according to whether β_0 started a differential too small or too large, diverging more and more from it until, for γ equals zero and β equal to either zero or π the divergence reaches a maximum in the cusp B_0 or B'_0. After this B is pulled by V and generates the symmetrical right-hand branch, which, for γ equal to plus infinity, winds up around the Zero-Circle.

The inner branches are always concave toward C, but the outer have points of inflection at B_1 and I for $\beta = \pm 90°$. The center of curvature J is readily found for any point by intersecting the line CV with a perpendicular to VB at B, and it may easily be seen that this intersection falls at infinity for β equal to $\pm 90°$.

In the neighborhood of Z and O there are evidently an infinite number of points where the right-hand and left-hand branches cross each other, quite close to the Zero-Circle.

THE CHEMICAL AND PHYSICAL EXAMINATION OF PAPER.

BY PROFESSOR THOMAS B. STILLMAN.

This subject may be conveniently divided into eight sections:

First.—Determination of the nature of the fibre.

Second.—Microscopical examination.

Third.—Determination of free acids.

Fourth.—Determination of the nature and amount of the sizing used.

Fifth.—Determination of the amount of ash and its analysis.

Sixth.—Determination of the thickness of the paper.

Seventh.—Determination of the weight per cubic decimeter.

Eighth.—Determination of the absolute breaking strength.

First.—The introduction, in late years, of the various kinds of wood fibres in the manufacture of paper has rendered the chemical examination of the same exceedingly difficult.

This is more especially so where the wood fibre has been subjected to chemical treatment, as in the "sulphite process" or the "soda process," before being incorporated in the paper.

Nearly all of the chemical reactions for the recognition of the wood fibres in paper produce certain colors with the various resins in the wood when the reagent is added. While the fibre prepared entirely by the "mechanical" process can be indicated without difficulty, even when mixed with cotton and linen in various amounts, the conditions are greatly altered when the wood fibre has been subjected to bleaching and chemical treatment, since the latter removes much of the resinous matters of the wood and increases the difficulty of the qualitative examination.

The chemical reactions of the fibres produced from the various woods used in paper-making, pine, poplar, and spruce, are identical, qualitatively, with the following reagents.

1. Hydrochloric acid and Phloroglucin produce a red color with "mechanical" wood pulp.

2. Aniline Sulphate produces a yellow color.

3. Naphtylamin and Hydrochloric acid produce an orange yellow color.

4. Anthracene Hydrochlorate produces a red color.
5. Phenol Hydrochlorate produces a bluish-green color.
6. Concentrated HCl produces a violet color.
7. Pyrrol and HCl produce a purple red color.
8. Pyrogallic acid and Zinc Chloride produce a dark violet color.
9. Nitric and Sulphuric Acids produce a red color.
10. Haematoxylin Solution produces a red color.
11. Alcoholic Solution of Cochineal produces a blue violet.

Where the wood pulp is composed entirely of "mechanical" wood fibre the above reactions are very marked, and, by the aid of the microscope, the varieties of wood can be determined.

Wood pulp produced by the "soda" or by the "bi-sulphite" process gives a much weaker reaction with the chemical reagents used for identification, and in many instances where the pulp has been used many times in paper-making will give no color reactions sufficient for recognition. The amount of "mechanical fibre" in a mixture of "chemical fibre," linen fibre, cotton fibre and "mechanical" fibre in a paper can be determined as follows:

The sample of paper is first boiled in water, then in alcohol, and afterwards digested with ether. After drying, a solution of chloride of gold is added.

Linen, cotton, and "chemical" wood fibre have no reducing action upon the solution of gold; but the mechanical wood fibre immediately reduces gold from the solution, this action being due to the ligno-cellulose remaining in the mechanical wood fibre.

One hundred grammes of mechanical wood pulp, under above conditions, will reduce 14,285 grammes of gold.*

If a sample of paper be submitted for examination as to the fibres used in its manufacture, the following preliminary work is requisite: The rosin, sizing, filling, etc., in the manufactured paper must first be removed. Cut the paper into small pieces, place them in a beaker and digest with a solution of caustic soda (NaOH, 1 part, H_2O, 30 parts), at a moderate heat, for ten minutes. Pour off the liquid, replace with double

* *Handbuch der Technisch-Chem. Untersuchungen* (BOLLEY). *6th Auf.*, page 1007.

the amount of distilled water, and warm ten minutes; pour off this liquid, and repeat once. Now place the paper in a solution composed of one part of Hydrochloric acid and fifteen parts of distilled water and digest ten minutes. Wash a number of times with distilled water, until washings are no longer acid; then dry.

Suppose the sample of paper so treated to be composed of a mixture of "mechanical" wood fibre, chemical wood fibre, linen, and cotton—a mixture to be found in many samples of good quality of writing-paper.

A sample of the dried paper is tested with solution of gold chloride. If no reduction of gold takes place, the indications point to the absence of mechanical wood fibre. This, however, is not absolute, since, if the paper has been made from "cuttings," "old paper stock," etc., etc., the mechanical wood pulp might have been treated quite a number of times by chemicals in the production of the finer quality of paper, and its lignocellulose destroyed or modified in such a way as to nullify the gold test.

Generally speaking, however, the reduction of the gold chloride is indicative of the presence of mechanical wood fibre.* †

R. Bendikt (Chem. Zeit., XV., p. 201) gives a method for the determination of mechanical wood fibre in paper, dependent upon the methyl numbers of lignin contained in it. This process has been tested by W. Herzberg (*Mitt. König. tech. Versuchs.*, *1891, 44–50*), with the result that preference is given to the use of gold chloride solution.

If the amount of mechanical wood fibre in a paper amounts to about ten per cent., GOTTSTEIN (Papierzeitung, 1884, 432) states that the fibres may be counted under the microscope, after the fibres have first been made visible by a treatment with an alcoholic phloroglucinol solution and hydrochloric acid. Fifteen per cent. or more of the mechanical wood fibre in the

* "Ueber die quantitative Bestimmung des Holzschliffs im Papier," von Rich. Godeffroy und Max Conlon; *Mittheilungen aus dem K. K. Technologischen Gewerbemuseum in Wien.* 1888.

† *Mittheilungen aus den Königlichen technischen Versuchsanstalten zu Berlin*, 1892, p. 54.

mixture renders the test valueless. If chemical wood fibre be present in a paper with mechanical wood fibre, no color tests for the former are positive in the presence of the latter, since the mechanical wood pulp possesses a greater tinctorial power.

Should mechanical wood fibre be absent, however, a solution of Resorcin can be applied to a properly prepared sample of the paper. Chemical wood fibre produces a violet color, whereas cotton and linen are without action.

A solution of Phenol also produces a violet color under similar conditions.

Second.—By careful manipulation of the microscope, the fibres of linen, cotton, and the various woods can be recognized.

The distinction must be noted here, however, that the fibres from paper, no matter what the source, do not have the appearance under the microscope that they possessed before the mechanical and chemical treatment required in the manufacture of paper.

The chemical process in paper-making is very severe upon the various fibres, since they are subjected to beating and cutting in the "beating-machine," to protracted maceration in strong alkali, to digestion in boiling water, to bleaching with chloride of lime, are loaded with various clays, and finally are sized, and often burnished.

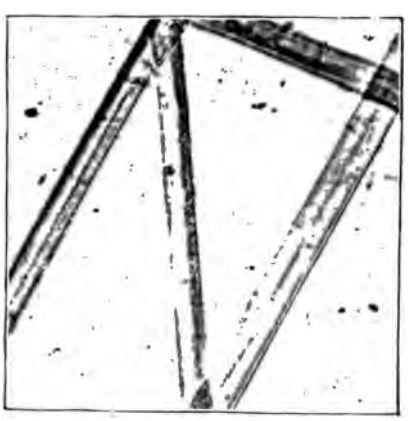


FIGURE 1

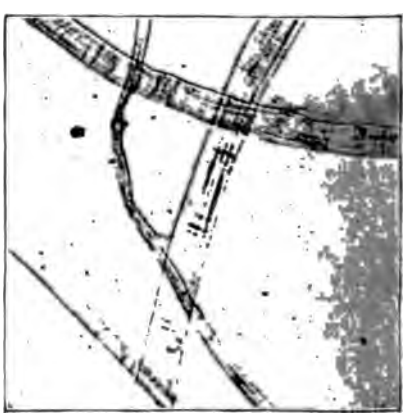


FIGURE 2.

This difference between linen fibres before and after treatment is shown in Figs. 1 and 2.

A comparison shows not only a radical change in the form of the fibres, but a difference in the transparency, due to removal of soluble portions of the fibre.

FIGURE 3.

FIGURE 4.

Poplar wood fibre (Fig. 3), made by chemical process, under the microscope resembles the fibres of linen more than does any other of the wood fibres. It, however, has one distinguishing characteristic, even among the disintegrated pulps,

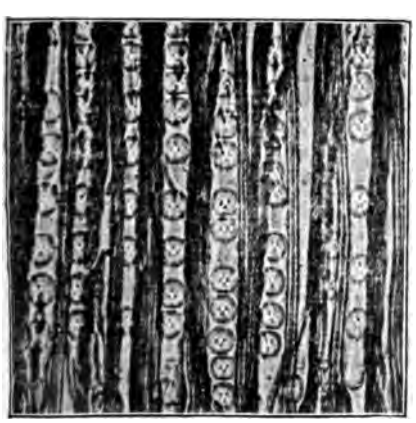


FIGURE 5.

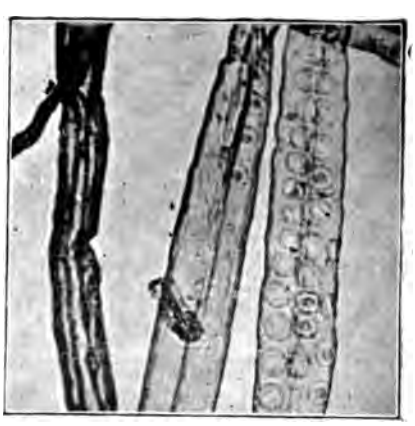


FIGURE 6.

that is, the tangential fragments have among them particles bearing a grate, or screen-like, appearance, as shown in Fig. 4.

The coniferous woods used in paper-making show peculiarities in structure entirely different, under the microscope, from linen and cotton, the most distinctive one being the small circular "pits" or spots along the centre of each fibre. A section of spruce wood, composed of fifteen or more fibres, is shown in Fig. 5.

After pulping and making into paper, spruce fibre has the appearance, under the microscope, shown in Fig. 6. It still retains the peculiar circular markings, and is readily distinguished from the linen paper fibre, Fig. 2, or from cotton fibre, Fig. 7.

FIGURE 7.

FIGURE 8.

In Fig. 8 is shown the peculiar "centre-marking" of coniferous fibre, as taken from a sample of writing-paper sold as linen paper, but shown by both chemical and microscopical examination to be composed largely of spruce fibre and linen.*

The microscope will thus determine the differences between the various fibres used in paper-making, and, by properly arranged apparatus connected therewith, the percentage of each variety of fibre.

* The micro-photographs used in this article (Nos. 1 to 8) are from specimens made during an investigation upon fibres of papers by Charles S. Shultz and the writer in 1893, and represent the fibres magnified 200 diameters.

According to the German official directions, the sample of paper, after removal of sizing, etc., is to be steeped in a solution of 1.5 grms. of iodine and 2 grms. of potassium iodide in 20 c. c. of water and then examined under the microscope. The fibres may be conveniently divided into three groups:

1. Linen, hemp, and cotton.

2. Wood-cellulose ("chemical" wood fibre), straw-cellulose, and esparto.

3. Ground wood-celluluse and jute.

After treatment with the above solution, the fibres of group 1 are stained brown, those of group 2 are not colored, whilst the strongly lignified fibres of group 3 are colored yellow. But it has been found that this method is somewhat defective; the cellulose of group 2, for example, being invariably to some extent stained, whilst the members of group 1 are so deeply colored that it is almost impossible to distinguish their structural characters. After many experiments, the following method was found most satisfactory.

The paper is placed on the object-glass of the microscope and treated with iodine solution, the unabsorbed iodine removed by means of filter paper, and the paper covered with sulphuric acid dilute. The solution of iodine in potassium iodide should be of such a strength that a layer of 3 cc. thickness should be of ruby-red color and quite transparent. The paper is now removed and boiled with a solution of dilute potassium hydrate, washed thoroughly, and replaced on the object-glass. The color reactions are as follows:

1. Cotton, linen, and hemp take a violet-red or wine-red color.

2. Well bleached wood-cellulose and ordinary bleached straw-cellulose are colored gray-blue or pure blue, without any tinge of red.

3. Unbleached or imperfectly bleached wood fibre absorbs very little iodine and remains colorless.

4. Strongly lignified fibres, such as ground wood-cellulose and raw jute, are colored yellow.

The numbers of each variety of fibre are now carefully counted by means of the microscope and an eye-piece mi-

crometer ruled in squares. This chemical treatment and microscopical examination is to be repeated upon at least fifty different pieces of paper from different parts of the sample, and an average taken. By this means approximate percentages of each variety of fibre in the paper can be stated. (*Jour. Soc. Chem. Industry, VIII., 564.*)

(*To be continued.*)

CHANGE IN RATING FOR FEED WATER HEATERS.

The practice of rating Feed Water Heaters on a horse-power basis, a practice which was misleading and had nothing to commend it, has been discontinued by the members of The Feed Water Heater Manufacturers Association ; and they have agreed among themselves to state in their catalogues and specifications, and whenever called upon to make prices, the diameter of the tubes, the number of lineal feet thereof, and the total square feet of heating surface in the heater offered.

RESULTS OF MEASUREMENTS TO TEST THE ACCURACY OF SMALL THROTTLING CALORIMETERS.*

BY PROF. D. S. JACOBUS.

The following data are the results of tests made as a preliminary to an investigation, undertaken for the Babcock & Wilcox Co. by Professor Denton, to determine the conditions under which throttling calorimeters applied to a steam main are a reliable means of determining the average amount of moisture in the total quantity of steam flowing through it.

The results of the experiments tend to confirm the opinion that the indication of these instruments may greatly exaggerate the amount of moisture, and that the degree of inaccuracy depends upon the local conditions.

It was thought desirable, therefore, to bring the matter to the attention of the Society, and invite discussion, so that subsequent experiments might cover the conditions of any peculiar experiences of members in this line.

The tests indicate that various calorimeter nozzles, such as are now used in practice, do not give an average sample of the steam which flows by them. A throttling calorimeter gives the correct amount of moisture in the steam which passes through the throttling orifice, so that the entire error is due to the fact that an average sample of steam is not supplied to the calorimeter.

If a nozzle closed at the inner end, and perforated with a number of small holes in its cylindrical surface, is employed, the calorimeter will ordinarily indicate too high a percentage of moisture. For example, a calorimeter attached to a three-inch horizontal pipe by means of a horizontal nozzle of half-inch pipe, having six holes seven-thirty-seconds inch in diameter, indicated 6.3 per cent. of moisture when the actual amount

*From a paper presented at the New York meeting (December, 1894) of the American Society of Mechanical Engineers, and forming part of Volume XVI. of the *Transactions*.

TABLE I.

COMPARISON OF ACTUAL PERCENTAGES OF MOISTURE WITH AMOUNTS INDICATED BY A THROTTLING CALORIMETER; STEAM PASSING THROUGH A THREE-INCH HORIZONTAL PIPE WITH A VELOCITY OF ABOUT FORTY-FIVE FEET PER SECOND.

No. of Test.	Character of Nozzle.	Steam passing through 3-in. pipe in lbs. per hour, including moisture shown in Col. 6.	Pressure of steam in lbs. per square inch above atmosphere.	Percentage of moisture by Barrus calorimeter.	Correct percentage of moisture determined by weighing water injected into steam pipe.	Remarks.
1	2	3	4	5	6	7
1	Vertical nozzle No. 1 with 12 holes $\frac{7}{32}$ in. diameter	1698	80	5.5	2.5	
2		1877	80	9.3	3.3	
3		1768	80	11.1	4.7	
4		1788	80	20.9	10.9	
5		2003	80	31.8	19.1	
6		2381	80	47.9	36.5	
7	Vertical nozzle No. 2 with 12 holes ⅛ in. diameter	1916	78.5	54.6*	21.0	
8		2044	78.9	50.8*	17.6	Separator of calorimeter and heat gauge both in use.
9	Horizontal nozzle No. 3 with 6 holes $\frac{7}{32}$ in. diameter	1538	80	6.3	2.3	
10		1586	80	8.4	3.2	
11		1525	80	14.6	8.8	
12		1637	80	17.8	10.1	
13		1745	80	37.4	23.0	
14		2187	80	46.9	37.2	
15	Nozzle No. 4. Slot away from current	1577	80	5.6	1.0	
16	" " " toward "	1576	80	0.1	1.4	
17	" " " at right angles to current	1578	80	2.5	1.2	
18	Horizontal nozzle No. 3 with 6 holes $\frac{7}{32}$ in. diameter†	1810	80	1.0	.5	Only heat gauge of calorimeter in use.
19		1815	80	1.5	.8	
20		1818	80	2.2	1.0	
21		1830	80	3.6	1.6	

* In these tests the calorimeter was attached to the horizontal pipe marked E in Fig. 1, and the conditions were such that it is probable that moisture ran along the bottom of the pipe and entered the lower holes of the nozzle. In all the other tests the calorimeter was placed in the position marked L in Fig. 1.

† In these tests the true percentages of moisture given in Column 6 were calculated from the superheating of the steam in the 12-inch drum, which was shown to give the same results as those obtained by weighing the water injected.

was 2.3 per cent.; 14.6 per cent. when the actual was 8.8 per cent., and 17.8 per cent. when the actual was 10.1 per cent. In these tests about 1,500 pounds of steam flowed through the pipe per hour.

A calorimeter attached to a vertical nozzle with twelve holes seven-thirty-seconds inch in diameter, placed in the same horizontal pipe, indicated 5.5 per cent. when the true amount was 2.5 per cent.; 11.1 per cent. when the true amount was 4.7 per cent., and 20.9 per cent. when the true amount was 10.9 per cent.

A vertical nozzle, containing twelve holes one-eighth inch in diameter, also gave too high percentages of moisture. The results of the tests are given in detail in Table I.

These results show that other devices than perforated nozzles should be employed to obtain an average sample of steam, and tests are in progress to determine the efficiency of an arrangement devised by Professor Denton, which consists of a tube passing through a stuffing-box, and so arranged that it may be moved to any position across the pipe under a full head of steam. The tube has an open end, and there are no side holes. This arrangement allows determinations to be made at all depths.

Lines 15, 16, and 17 of Table I. give the results obtained with a special form of nozzle, in which a slot was cut about one-quarter inch wide and one inch long. This slot was placed so as to be at the centre of the three-inch pipe. When the slot was turned so that the current of steam struck directly against it, the percentage of moisture indicated by the calorimeter was less than the true amount, and when turned so that it was away from the current the percentage of moisture was greater than the true amount. When placed at right angles to the current, an intermediate result was obtained, which was greater than the true amount of moisture. These experiments tend to show that the water which strikes a nozzle clings to it and passes around it so as to be drawn inward by the currents of steam entering the apertures.

The true percentage of moisture was determined as follows: A known weight of water at a temperature of about 65° Fahr. was injected into a three-inch pipe, and travelled along

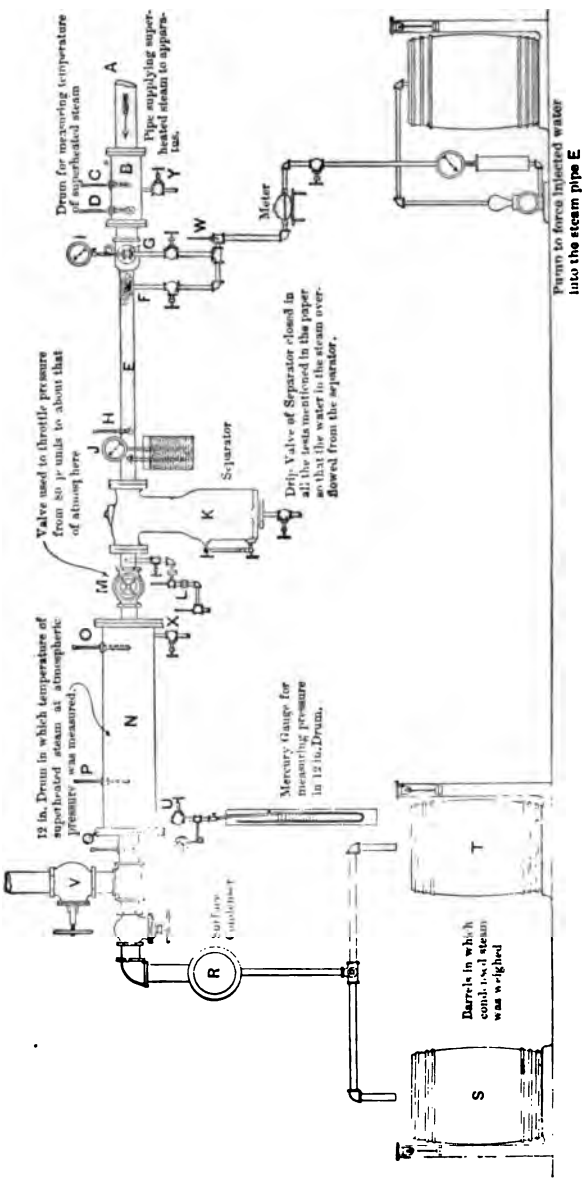

Drum for measuring temperature of superheated steam
Pipe supplying superheated steam to apparatus.
Meter
Pump to force injected water into the steam pipe E
Valve used to throttle pressure from 80 lb. units to about that of atmosphere here
Separator
Drip Valve of Separator closed in all the tests mentioned in the paper so that the water in the steam overflowed from the separator.
12 in. Drum in which temperature of superheated steam at atmospheric pressure was measured.
Mercury Gauge for measuring pressure in 12 in. Drum.
Surface Condenser
Barrels in which condensed steam was weighed
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
X
Y

FIGURE 1.

with the steam for the distance of about eight feet into a three-inch Stratton separator. After leaving the separator the steam passed through a three-inch horizontal nipple six inches long into a twelve-inch drum four feet long. A valve between the nipple and twelve-inch drum was used to throttle the steam so as to obtain the desired rate of flow and maintain a pressure in the twelve-inch drum equal to about that of the atmosphere. The steam flowed from the twelve-inch drum through a system of piping into a surface condenser, and was finally weighed. The calorimeter nozzle was tapped into the three-inch nipple between the throttling valve and the separator at a distance of about three inches from the separator. The steam was turned at right angles in passing from the separator to the outlet pipe, so that the experiments correspond to placing calorimeters in a horizontal pipe near an elbow. The drip pipe of the separator was closed, and the water rose to such a height in the separator that it mingled with the steam passing from the same. This arrangement was adopted in order to obtain a thorough mixture of the steam and water. At first a baffle-plate device was contemplated, but on further consideration the separator was used as an equivalent. That there was a fairly uniform mixture is confirmed by the fact that the horizontal nozzle gave about the same results as a vertical nozzle.

The general arrangement of the apparatus is shown in Fig. 1. Steam entered through the three-inch pipe at *A*, and passed into the 6-inch drum *B*, where the superheat was measured by means of the thermometers *C* and *D*. The thermometer *C* was placed in an ordinary mercury well, and the thermometer *D* in a mercury well having a thin neck and a bulb of metal at its lower end, as explained later on. The thermometer placed in the well having the bulb at the lowest end was found to give a higher reading than one placed in the ordinary form of well. From the 6-inch drum *B* the steam passed into the horizontal 3-inch pipe *E*. Water was injected through the nozzle *F*, in which two jets were made to impinge on each other and thus produce a fine spray, or through a plate perforated with holes one-eighth of an inch in diameter. The temperature of this water was measured at *W*. The temperature of the mixture of steam and water was measured at *H*, the reading in all cases

being that corresponding to saturated steam at the pressure existing in the pipe *E*. The pressure was measured be means of the two gauges *I* and *J*. The syphon connecting the guage *J* with the pipe *E* was surrounded with water so as to prevent overheating. The steam and water passed into the separator *K*, the drip of which was closed so that all the moisture in the steam passed through the separator. The Barrus calorimeter *L* was placed in the 3-inch nipple which formed the outflow of the separator. *M* is a valve which was employed to regulate the rate of flow, and to throttle the steam so that it was very nearly at atmospheric pressure in the 12-inch drum *N*. The temperature of the steam in the 12-inch drum was measured by means of the thermometers *O* and *P*, the thermometer *O* being placed in a mercury well, and the thermometer *P* coming directly in contact with the steam. The thermometer *Q* measured the temperature of the steam on leaving the 12-inch drum. From the 12-inch drum the steam entered the condenser *R*, and the condensed steam was finally weighed in the barrels *S* and *T*. The pressure in the 12-inch drum was measured by means of a gauge and a mercury manometer attached to the pipe *U*. *V* is a valve through which the steam could be allowed to escape into the atmosphere.

The valve *M* and the drum *N* constitute a large throttling calorimeter, so that if we know the percentage of moisture in the steam before passing through the valve *M* we can compare it with the value obtained by calculation from the superheating observed in the drum *N*. The true percentage of moisture was calculated from the weight and temperature of the water injected at *F* or *G*, together with the superheating of the steam in the drum *B*, and the results by the two methods were found to agree within one-fifth of one per cent. up to a range nearly equal to the maximum capacity of a throttling calorimeter at the existing pressures. When the thermometers in the drum *N* registered about 220 degrees a slight drip of water would appear at the valve *N*, thus showing that all the moisture had not been evaporated, but up to this limit the percentage of moisture calculated from the superheating agreed with that obtained by weighing the amount of water injected.

A constant amount of moisture was maintained by taking

weighings of the condensed steam and water every five minutes, and regulating the flow of water to a uniform rate. A continuous record was preserved, and only that portion where uniform conditions were maintained was employed in calculating the final results. The average length of such selected intervals was about twenty-five minutes, so that five readings of weights were used in calculating the results of each test. The readings of temperatures were made every two and one-half minutes.

The height of water in the separator was observed and found to remain at a constant figure for a given set of conditions. A few of the tests were also extended over several hours, and no practical variation was detected.

In all the tests the steam was allowed to flow through the apparatus for some time before taking the readings.

Tests Nos. 7 and 8 are exceptions to the others. In these the calorimeter was attached to the three-inch pipe *E* leading to the separator, and within about one foot of the same. The results shown by the calorimeter in these tests are very high, 54.6 per cent. being indicated, when the true amount was 21.0 per cent., and 50.8 per cent. when the true amount is 17.6 per cent. These results were probably caused by water running along the bottom of the pipe, which splashed upward into the lower holes of the nozzle.

In a special series of experiments it was shown that if the velocity was decreased to about one-third that which existed in the main steam-pipe during the experiments quoted in Table I., the percentages of priming indicated by the calorimeter were less than the true amount. Such low velocities (fifteen feet per second), however, seldom occur in practice, and the results were therefore not included in the paper.

As very slow velocities tended to produce too low indications of moisture for the conditions under which the tests were made, and higher ones approaching those employed in practice tended to give indications which are too high, there may have been a particular velocity for a given set of conditions at which a nozzle would have given correct results.

At first it was thought that a portion of the discrepancy found in the tests with the calorimeter might be due to the

cooling effect of the low-pressure steam which came in contact with one side of the valve *M*, Fig. 1, and which might tend to cool the main pipe into which the calorimeter was inserted at *L*. Such, however, was not the case, as a thermometer placed in a short well in the pipe directly over the calorimeter nozzle gave the same indications as a thermometer placed at *H*. The fact that the results given by the small calorimeter, and the true percentages of priming as given by the temperature in the 12-inch drum, tend to approach each other for dry steam, also shows that the pipe into which the calorimeter nozzle was inserted could not have been cooled to any great extent. Again, in the tests at low velocities of steam the readings given by the small calorimeter were less than should have been, which is in the reverse direction to the action that should take place if the pipe was cooled by conduction of heat to the valve *M*.

The nozzles were all of half-inch pipe, and were of the following forms:

Nozzle No. 1 contained twelve holes, seven-thirty-seconds of an inch in diameter, drilled along four equidistant lines parallel to the centre line of the pipe. The centres of the four holes nearest to the outlet were about three-quarters of an inch from the inner surface of the three-inch pipe when the nozzle was screwed into place. The holes drilled along each line were about three-quarters of an inch apart.

Nozzle No. 2 was of the same form as No. 1, except that the holes were one-eighth inch in diameter, and the holes nearest the outlet were within three-eighths of an inch of the inner surface of the pipe when the nozzle was screwed into position.

Nozzle No. 3 contained six holes seven-thirty-seconds of an inch in diameter, drilled along two lines parallel to the centre of the pipe and opposite each other. When in position the plane in which the holes were drilled was horizontal. The holes nearest the outlet were within three-quarters of an inch of the inner surface of the pipe. The holes were three-quarters of an inch from each other, as in nozzles Nos. 1 and 2.

Nozzle No. 4 has already been described in connection with the tests made with it.

The nozzles were made with long threads, so that all th

portion projecting into the three-inch steam-pipe was threaded. All were closed at their inner ends.

To measure the amount of superheat in the steam the thermometer *D* was placed in a special form of mercury well, having a bulb at its lower extremity, and provided with a very thin neck leading from this bulb to the outside of the pipe. The large bulb, combined with the thin neck, overcomes the error introduced by conduction of the pipe to the well, which, in a well of a three-eighths-of-an-inch pipe four inches long, amounts to about four degrees Fahr. This large error occurs only in the case of superheated steam.

The drum *B* was much cooler than the superheated steam near its centre, for with superheating to the extent of ten to fifteen degrees at the centre, water could be drained from the drip valve *Y*. The great difficulty of estimating the correct degree of superheating of the entering steam led to a series of preliminary tests, in which coefficients were determined which represented the heat units per pound of steam, including all radiation effects, corresponding to a given amount of superheat, as registered by the thermometers *B* and *C*. In these tests no water was injected into the steam pipe, and the entire volume of superheated steam passing through the apparatus was throttled at *M*, and its temperature, after throttling, measured in the 12-inch drum *N*.

For the higher rates of flow the coefficient was found to be 0.47, and for the lower rates 0.45. These figures are equivalent to the specific heat of the steam less the radiation effect of the apparatus, but are not exact physical quantities, because the temperature indicated by the thermometers employed to measure the superheat of the steam may not have given the correct average for all the steam passing through the drum in which they were placed. All portions of the apparatus were well covered with hair felt. This method of allowing for the initial superheating of the steam was checked up to the limit of moisture that could be indicated by superheating in the 12-inch drum, and was found to agree within one-fifth of one per cent.

Whenever the amount of moisture was low enough to cause the steam in the 12-inch drum to be superheated, the percentages

obtained by weighing, given in Table I., were checked by the percentages obtained by calculation from the superheat.

The basis of pressure was a plug device, which was loaded with weights so as to correspond to the required pressures. The plug was one-half inch in diameter, and the hole in the bushing into which it fitted was 0.5005 inch. Both the plug and the bushing were ground true, and were the work of the Pratt & Whitney Company. The readings obtained with this plug were checked by the square-inch knife-edge piece device of the Utica Steam Guage Company, and by a mercury column.

To standardize the thermometers, they were placed in the mercury wells in which they were used, or in similar ones, and subjected to a known pressure of saturated steam. The corrections were made by employing Regnault's values for the temperature of saturated steam, so that the final readings correspond to the temperatures by an air thermometer. In general, if the entire column of mercury in the thermometer is heated, the reading indicated by the same will be too high; whereas, if a large portion of the column of mercury contained in the stem is not heated, the reading will be too low.

The radiation of the Barrus calorimeter was determined by passing superheated steam through it. The separator portion was filled with water to a given height in the glass, and the temperature of the superheated steam was adjusted so that the water level remained constant in the glass. If the water increased in height, the temperature of the entering steam was increased so as to re-evaporate some of the water; and if it fell too low, the temperature of the steam was decreased. The tests were extended over several hours. An average of the loss of superheat represents the losses by radiation. To determine the radiation of the heat gauge portion, the orifice was removed, and superheated steam was passed through the apparatus at the same rate as if the orifice had been present. In this case the loss of superheat also represented the loss by radiation.

It was difficult to ascertain the average temperature of the superheated steam entering the apparatus, as has been previously explained, and this, together with the fact that the effect of radiation should be considered, led to experiments to determine the total heat of the superheated steam at the initial pres-

sure for various readings of the thermometers which registered the superheating in the 6-inch drum marked B in Fig. 1. The total heat of the superheated steam at entrance was taken as the total heat of saturated steam at the observed pressure, plus some factor corresponding to the specific heat of steam, multiplied by the degrees of superheating registered by the thermometers, and this factor was deduced from the experiments.

Let p_1 and p_2 be the pressure in the 6-inch drum marked B in Fig. 1, and in the 12-inch drum marked N, into which the steam passed after being throttled by the valve M; t_1 and t_2, the temperatures of saturated steam at the above pressures; S_1 and S_2, the temperature of the superheated steam; H_1 and H_2, the total heats of saturated steam; R, the heat lost by radiation of each pound of steam in passing through the apparatus, and X, the heat factor, as above explained. We then have,

$$H_2 + 0.48\,(S_2 - t_2) + R = H_1 + X\,(S_1 - t_1) \quad . \quad . \quad . \quad . \quad (1)$$

$$X = \frac{H_2 + 0.48\,(S_2 - t_2) - H_1 + R}{S_1 - t_1}.$$

If the heat lost by radiation is deducted from the total heat of the steam passing the 6-inch drum, we may then obtain a factor X_1, which, on being used in the right-hand member of equation (1), will give the total heat in one pound of the steam when it leaves the separator, provided that no water is injected into the pipe. This factor is, therefore,

$$X^1 = \frac{H_2 + 0.48\,(S_2 - t_2) - H_1}{S_1 - t_1}.$$

The data and calculated values of X^1 are given in Table II. In each test uniform conditions were maintained, and a continuous record was taken for from two to three hours. Only the last portion of the records was used in obtaining the average data given in the tables, as it was found that considerable time elapsed before the effect of radiation and conduction became constant.

The universally accepted figure for the specific heat of steam is 0.48, which is derived from Regnault's experiments. In these experiments the range of temperature was from about 260 degrees Fahr. to 430 degrees Fahr. In tests with throttling calorimeters it is necessary to know the total heat of superheated steam at atmospheric pressure. This is usually taken

TABLE II.

Determination of heat factor X^1, by which the degrees of superheating, as registered by thermometers placed in the drum marked B in Fig. 1 must be multiplied in order to obtain a quantity which, if added to the total heat of saturated steam, will give the total heat of the superheated steam on leaving the separator, A. This factor includes the effect of radiation, so that it varies with the amount of steam flowing through the apparatus. The readings of the thermometers are all corrected so as to correspond to temperatures registered by an air thermometer.

Number of Test.	Weight of steam in lbs per hour.	Pressure in lbs. per square inch above atmosphere.		Temperature corresponding to pressure, in degrees Fahr.		Temperature of superheated steam as registered by thermometers, Degrees Fahr.		Total heat of saturated steam above zero. Degrees Fahr. in B. T. U.		Heat factor, X^1, corresponding to readings of thermometers in 6-inch drum, and including radiation.
		Initial.	Final.							
		p_1	p_2	t_1	t_2	S_1	S_2	H_1	H_2	$\frac{H_2 + 0.48\,(S_2 - t_2) - H_1}{S_1 - t_1}$
1	600	80	0.2	323.7	212.7	360.9	314.7	1212.6	1178.8	0.409
2	680	80	0.2	323.7	212.7	356.9	313.6	1212.6	1178.8	0.452
3	700	80	0.2	323.7	212.7	370.7	326.7	1212.6	1178.8	0.445
4	1400	80	0.8	323.7	214.7	356.8	316.1	1212.6	1179.4	0.468
5	1425	80	0.8	323.7	214.7	350.0	308.9	1212.6	1179.6	0.457
6	1560	80	1.0	323.7	215.3	373.9	332.5	1212.6	1179.6	0.464

as the total heat of saturated steam at atmospheric pressure, plus the degrees of superheating, times 0.48. This may not be precisely so, as it has not been shown that the factor of 0.48 applies over the range from the temperature of saturation, or 212 degeees Fahr., to the lowest temperature of Regnault's experiments, or 260 degrees Fahr.

In Regnault's experiments on the specific heat of steam he determined the total heats of superheated steam at two different temperatures, and divided the difference of the total heats by the difference of temperature in order to obtain the specific heat.

The average results of his experiments are given in Table III. Table IV. contains a comparison of the total heats of superheated steam at atmospheric pressure, as indicated by the

TABLE III.

REGNAULT'S EXPERIMENTS TO DETERMINE THE SPECIFIC HEAT OF STEAM.

	Tests with Lowest Amounts of Superheating.			Tests with Greatest Amounts of Superheating.					
Number of series.	Number of tests in series.	Temperature of superheated steam, in degrees Fahr.	Total heat in B. T. U. per lb. above 32 degrees Fahr.	Number of tests in series.	Temperature of superheated steam, in degrees Fahr.	Total heat in B. T. U. per lb., above 32 degrees Fahr.	Difference of temperature, in degrees Fahr. Col. 6 —Col. 3.	Difference of total heats per lb. in B. T. U. Col. 7—Col. 4.	Specific heat of steam. Col. 9—Col. 8.
1	2	3	4	5	6	7	8	9	10
1	5	261.86	1166.27	3	448.00	1253.54	186.16	87.27	0.4688
2	3	279.91	1184.45	3	438.55	1260.77	158.64	76.32	0.4811
3	10	255.76	1162.39	4	410.79	1236.92	155.03	74.54	0.4808
4	6	252.95	1161.79	7	420.85	1242.32	167.90	80.53	0.4796
								Average	0.4776

NOTE.—Regnault remarks that if we neglect the first series, which is not as reliable as the others, the average is 0.4805.

experiments, with the total heat calculated by employing the factor of 0.48.

A graphical representation of the results of Regnault's experiments is shown in Fig. 2. The average results of each series of tests are indicated by dots enclosed in circles. The crosses represent the six tests which form the second series. An examination of Fig. 2, together with the figures given in Table IV, shows that the results for the total heats vary among themselves, the results for the second series of tests being above the theoretical value in which the specific heat is taken as 0.48, and the remainder below this value.

As Regnault remarks that the first series of tests are not as reliable as the others, we will consider only the data furnished by the remaining series.

In Fig. 2 it may be observed that the six separate experiments of the second series, which are indicated by the crosses,

TABLE IV.

COMPARISON OF THE TOTAL HEATS OF SUPERHEATED STEAM AS DETERMINED BY REGNAULT'S EXPERIMENTS WITH VALUES OBTAINED BY EMPLOYING THE EQUATION:

Total heat in B. T. U., above 32 degrees Fahr. $= 1146.6 + 0.48 \times$ degrees of superheating.

Number of series.	Tests with lowest amounts of superheating.				Tests with greatest amounts of superheating.			
	Temperature in degrees Fahr.	Total heat in B. T. U., above 32 degrees Fahr.			Temperature in degrees Fahr.	Total heat in B. T. U., above 32 degrees Fahr.		
		By experiment.	Calculated.	Difference.		By experiment.	Calculated.	Difference.
1	2	3	4	5	6	7	8	9
1	261.86	1166.3	1170.5	+ 4.2	448.00	1253.5	1259.9	+ 6.4
2	279.91	1184.4	1179.2	— 5.2	438.55	1260.8	1255.3	— 5.5
3	255.76	1162.4	1167.6	+ 5.2	410.79	1236.9	1242.0	+ 5.1
4	252.95	1161.8	1166.3	+ 4.5	420.85	1242.3	1246 8	+ 4.5

are all about the same distance above the line found by employing the factor of 0.48, thus showing that the experiments agree well among themselves, and that the difference between this series and the third and fourth is not due to anaccidental variation. The third and fourth series of tests were made with a larger calorimeter than was used in the second series, and it may be that the discrepancies in the total heats arise from some slight error in estimating the constants for the apparatus. Should there be such an error, it would affect the value determined for the specific heat but little, if at all, for the specific heat is calculated by taking the difference of the total heats, and a constant error in the total amounts would not affect the result. As the average of the two results, one for the calorimeter used in the second series of tests, and the other for the larger calorimeter used in the third and fourth series of tests nearly agree with the total heat calculated by employing the factor of 0.48, we have adopted this factor in our work.

We have made a number of experiments to show how

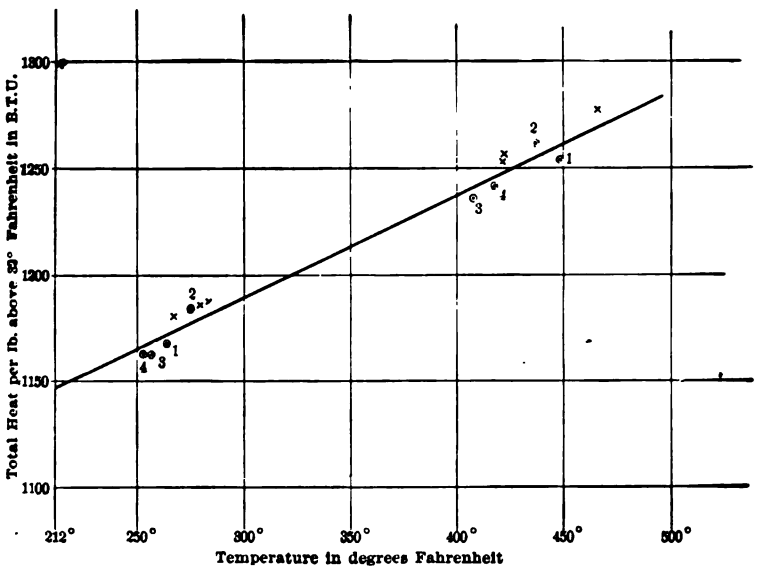


FIGURE 2.

nearly the above factor is correct as applied to calorimeters of the throttling principle, by starting with steam in a state of rest, or with moving steam just at the point of superheating, and passing it through a Barrus calorimeter. If the initial state of the steam is the same as the saturated steam of Regnault's experiments, and the factor of 0.48 is correct, then the temperature of the steam after throttling, or the normal reading, should be that obtained by the equation,

$$\text{Normal reading} = \frac{H_1 - H_2}{0.48} + t_2$$

In the first series of experiments to determine the normal reading, the calorimeter was attached to a vertical nozzle, with no side holes, in the same position in which it is shown in Fig. 1. This vertical nozzle drew the steam from the centre of the three-inch pipe. It was found that, with no other steam flowing through the pipe than that which passed into the calorimeter, the temperature of the steam leaving the calorimeter, corrected for radiation, with an initial steam pressure of 80 pounds, was 283 degrees Fahr. When the valve *M* was opened so as to allow the steam to pass the calorimeter nozzle at a

considerable velocity, higher normal readings were obtained than for steam in a state of rest, provided the steam was initially superheated, and was brought down to a state of saturation by injecting water into it. In such tests the excess of water was drawn out by the separator *K*, and the steam which passed into the calorimeter was drawn from the steam after this excess of moisture was removed. In these tests the temperature of the steam in the three-inch pipe was measured near the calorimeter nozzle by means of a thermometer, the bare bulb of which came in direct contact with the steam, and by means of a thermometer placed in a mercury well having a thin neck, of the form already described.

With the above arrangement, it was impossible, however, to bring the steam in the three-inch pipe just up to the point of superheating, and hold it at this point long enough to obtain reliable readings. The apparatus shown in Fig. 3 was therefore constructed.

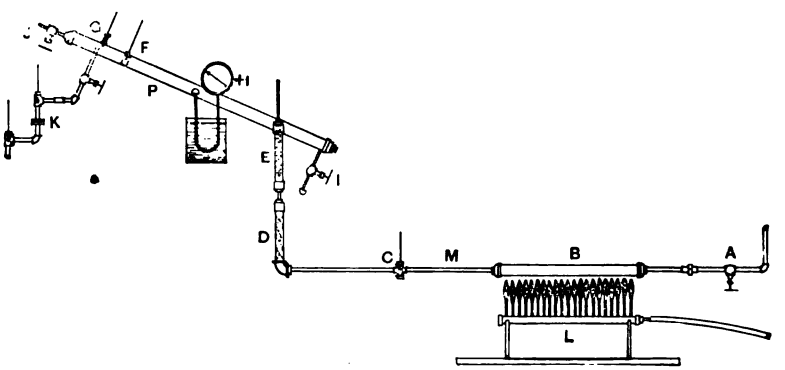


FIGURE 3.

In this apparatus the steam was admitted at *A*, and flowed into the horizontal pipe, *B*, where it was superheated by means of the gas burners, *L*. The temperature of the superheated steam was measured at *C*. A small stream of water was allowed to flow over the pipe *M* in some of the tests, so as to produce any desired degree of wetness in the steam. The wet steam was passed upward through the vertical pipe, *D*, which contained an augur-shaped piece which tended to thoroughly mix the water with the steam. The steam leaving *D* was passed

through a smaller pipe into the lower part of the vertical pipe, *E*, which contained a long mercury well for measuring the temperature. The steam then passed into the side of the three-inch pipe, *P*, which was placed at an angle of about 30 degrees, so that any moisture deposited in the pipe ran downward and was drawn out at the drip, *I*. The pressure was measured by means of the gauge, H. The thermometer at *F* was placed in a mercury well having a thin neck, and that at *G* passed through a stuffing-box, so that its bulb came in direct contact with the steam. The calorimeter nozzle had no side holes, and projected upward into the three-inch pipe so as to draw steam from the centre of the same. *J* is a valve that was opened in some experiments where the steam was made to flow past the calorimeter nozzle.

All parts of the apparatus, except the horizontal pipe, *M*, and the superheating pipe, *B*, were thoroughly covered with felting, to diminish the radiation. With this apparatus the steam could be brought just to the point of superheating, and could be maintained in this condition for a considerable period of time; and it was found that the normal reading of the calorimeter for steam in this condition was 286 degrees Fahr. The minimum normal reading was 283 degrees Fahr., which agreed with the experiments already described, where the calorimeter was attached to a vertical nozzle with no side holes, which projected upward into a horizontal three-inch pipe. The theoretical normal reading for an exit pressure corresponding to a temperature of 213 degrees Fahr., which was the temperature indicated by the Barrus calorimeter with saturated steam at exit, was 283.5 degrees Fahr.; so that, starting with steam in a state of rest, the normal reading for steam which is slowly condensing is about the same as the theoretical normal reading employing the factor of 0.48.

It is probable that the variation of the normal readings with quiescent steam is due to the presence of mist in the steam. As the steam becomes drier this mist is evaporated so that when the steam is just at the point of superheating the normal reading is higher than it is for steam which contains mist. With steam in a quiescent state in a pipe, and which is undergoing condensation on account of the radiation of the pipe the

normal reading corresponds to that steam containing the maximum amount of mist.

That there may be a difference in the condition of steam at a given temperature and pressure was appreciated by Professor Rankine, who makes the statement that a vapor near the point of liquefaction has the power of retaining suspended in it a portion of its liquid in a state of cloud or mist.

With steam initially just at the point of superheating, a slightly lower value of the factor for the specific heat should be employed, to make the theoretical normal reading conform with that obtained by experiment. We cannot, however, say which of the above states of steam, or if either of the above states, are the same as in the steam used in Regnault's experiments.

The method adopted by Mr. Barrus to determine the normal reading is to obtain the indications of the calorimeter when supplied with steam from the pipe to which it is connected, when the latter is open to the boilers, and there is no flow of steam through it, so that the pipe contains what Mr. Barrus calls "dead steam."* Our tests at 80 pounds pressure show, as we have already stated, that results obtained in this way agree with the theoretical normal readings, provided the sample is taken from a horizontal pipe by means of a vertical nozzle with no side holes. In the case of a nozzle with side holes, placed in a vertical pipe, however, we have not been able to obtain correct normal readings, apparently because of water which trickled down the side of the pipe or fell through the steam and entered the nozzle.

METHOD OF COMPUTING THE TRUE PERCENTAGE OF MOISTURE IN THE STEAM FLOWING THROUGH THE THREE-INCH HORIZONTAL PIPE.

The method which has already been described consisted in determining the percentage of moisture in the mixture of steam and the known weight of injected water. The data and calculations in detail for test No. 9 of Table I. are as follows:

* *Boiler Tests*, by Geo. H. Barrus, p. 259.

1. Duration of selected interval for which the average data is obtained, in minutes	30
2. Steam condensed in the condenser R, in pounds per hour	1476
3. Steam passing through orifice of Barrus calorimeter L, in pounds per hour	58
4. Water drawn from separator of Barrus calorimeter, in pounds per hour	4.10
5. Total steam and entrained water leaving the separator K, in pounds per hour = line 2 + line 3 + line 4 = W	1538
6. Water injected at P, in pounds per hour = w	45.6
7. Temperature of water injected at F, in degrees Fahr. = t'	72.6
8. Pressure of steam at J, in pounds per square inch above atmosphere	80.0
9. Sensible heat of steam corresponding to pressure at J, in B. T. U. = h	326.9
10. Temperature of steam corresponding to pressure at J, in degrees Fahr. = t''	323.7
11. Latent heat of steam corresponding to pressure at J, in degrees Fahr. = L	885.7
12. Temperature of superheated steam before injecting water, as registered by the thermometer D, in degrees Fahr. = t'''	352.4
13. Weight of the injected water w that was evaporated into steam on mingling with the superheated steam, in pounds,* $= \frac{0.47\,(t'''-t'')\,(W-w) - w\,(h-t')}{L}$	9.6
14. Total weight of water in the mixture of steam and water = line 6 — line 13	36.0
15. True percentage of moisture in steam on reaching the Barrus calorimeter at L = line 14 × 100 ÷ line 5	2.3
16. Water entering the twelve-inch drum N, in pounds = line 14 — line 4	31.9
17. True percentage of moisture in steam in twelve-inch drum = line 16 × 100 ÷ line 2	2.2

CALCULATION OF PERCENTAGE OF MOISTURE INDICATED BY THE BARRUS CALORIMETER.

1. Weight of water drawn from separator per hour, in pounds	4.10
2. Weight of steam flowing through orifice, in pounds per hour	58
3. Temperature after throttling, in degrees Fahr	281
4. Correction for radiation of heat gauge, in degrees Fahr	2.0
5. Correction for radiation of separator, in degrees Fahr	3.9
6. Correction for radiation of horizontal half-inch pipe leading from nipple to separator, in degrees Fahr	1.1

*In the tests in which there was a high percentage of moisture the injected water condensed a portion of the steam instead of being partly evaporated. The factor of 0.47 is obtained from the experiments given in Table II.

7. Temperature of steam after throttling, corrected for radiation of heat gauge, in degrees Fahr	283
8. Percentage of moisture in steam leaving separator	0
9. Percentage of moisture removed by the separator of the Barrus calorimeter = line 1 × 100 ÷ (line 1 + line 2)	6.6
10. Correction for radiation of separator and half-inch pipe in per cent. = $\frac{5.0 \times 0.48 \times 100}{885.7}$	0.3
11. Percentage of moisture indicated by Barrus calorimeter = line 9 — line 10	6.3

DETERMINATION OF THE PERCENTAGE OF MOISTURE INDICATED BY THE SUPERHEATING OBSERVED IN THE TWELVE-INCH DRUM MARKED *N* IN FIG. 1.

1. Pressure of steam before throttling, in pounds per square inch above atmosphere = p_1	80
2. Pressure of steam after throttling, in pounds per square inch above atmosphere = p_2	0.9
3. Sensible heat corresponding to pressure p_1 = h_1	326.9
4. Latent heat corresponding to pressure p_1 = L_1	885.7
5. Total heat corresponding to pressure p_2 = H_2	1179.5
6. Temperature corresponding to pressure p_2 = t_2	215.0
7. Temperature of superheated steam after throttling = S_2	240.2
8. Quality of steam = $\frac{H_2 + 0.48 (S_2 - t_2) - h_1}{L_1}$	0.976
9. Percentage of priming = 100 (1 — line 8)	2.4

SUMMATION FOR THE SINGLE TEST COMPUTED ABOVE.

1. The steam passing into the Barrus calorimeter contained 6.3 per cent. of moisture, whereas the average percentage contained in the steam flowing through the three-inch pipe to which the calorimeter was attached was 2.3 per cent.

2. The percentage of moisture in the steam entering the twelve-inch drum was 2.2, whereas the percentage calculated from the amount of superheating was 2.4 per cent. A number of comparisons of this kind were made, to check the moisture indicated by the superheating in the twelve-inch drum, and in each case the results agreed with each other within an average figure of $\frac{1}{8}$ of 1 per cent., the difference being sometimes in one direction and sometimes in the other.

TEST OF A SUPERHEATED STEAM PLANT.

(Schmidt System.)

BY PROFESSOR M. SCHROETER, OF THE TECHNICAL HIGH SCHOOL IN MUNICH.

Translated by ALBERT F. GANZ, '95.*

A summary, arranged by the translator, of the results obtained by Professor Schroeter in his tests of this remarkable engine plant, is here placed before the reader, in advance of Professor Schroeter's paper, in order that the attention of engineers may be arrested by the high performance recorded, and their interest excited to learn the design of this novel plant, the methods adopted in the test, and the conclusions arrived at by the distinguished author in his report.

SYNOPSIS OF GENERAL RESULTS OF TEST (COMPILED BY TRANSLATOR).

	Test 1.	Test 2.
Duration of test.....hours	6.1	7.73
Average boiler pressure gauge.....lbs.	168.0	170.00
Temp. of saturated steam at this pressure, °F.	373.8	374.00
Average actual temp. of steam.....°F.	662.0	675.00
Degrees of superheating.....	288.2	301.00
Total weight of coal used.....lbs.	601.0	747.00
Coal used per hour..... "	98.5	96.60
Total weight of water evaporated..... "	4740.0	5924.00
Water evaporated per hour..... "	777.0	766.00
Evaporation of boiler, per pound of coal, actual	7.88	7.93
Evaporation of boiler per pound of coal from and at 212° F.....	10.2	10.40
Average Brake H. P.....	61.7	62.20
Average I. H. P.....	71.25	75.37
Friction.....%	14.0	18.00
Coal used per hour per brake H. P.....lbs.	1.60	1.55
Coal " " " " I. H. P..... "	1.38	1.28
Water " " " " brake H. P..... "	12.6	12.3
Water " " " " I. H. P..... "	10.9	10.16

* From *Zeitschrift des Vereins Deutscher Ingenieure*, Band xxxix.

PROFESSOR SCHROETER'S REPORT.

After the progress in the construction of steam engines, made possible by raising the steam-pressure and dividing the expansion among several cylinders, had again reached its limit, the attention of engine builders was once more directed toward superheating the steam. This, as is well known, had been practically tried in a few places some forty years ago, but it was soon abandoned. The reasons for abandoning it were manifold. Probably the great improvements made by Sulzer and Corliss marked the deciding direction of progress; for the results obtained by expanding even saturated steam in several cylinders were far ahead of those previously derived from superheated steam; and the extreme difficulties encountered in the use of the latter, which difficulties could hardly be overcome in those years, were now entirely eliminated.

In the meantime a clear understanding of the thermal changes occurring between the cylinder wall and the steam had been reached through the labors of Hirn and the Alsace School; and, by means of the triple expansion engine, which so rapidly came to the front, the greatest economy was effected which is possible with all improvements in the application of saturated steam. The time had come at which those versed in the state of the art were prepared to take up superheating again; and there resulted a steady development of the system in connection with the early constructions and the application of the most modern improvements, more particularly in Alsace, the classical home of our modern views of the steam engine. The results so far made known [1] show the fact that the final improvements in the steam engine must be in this direction.

For these reasons the writer was particularly interested, when called upon in the summer of 1894, to make a test of an engine built according to an entirely new system, called by its

(1) Walther-Meunier: Anwendung der Dampfueberhitzung, Strassburger Verlagsanstalt, 1891.

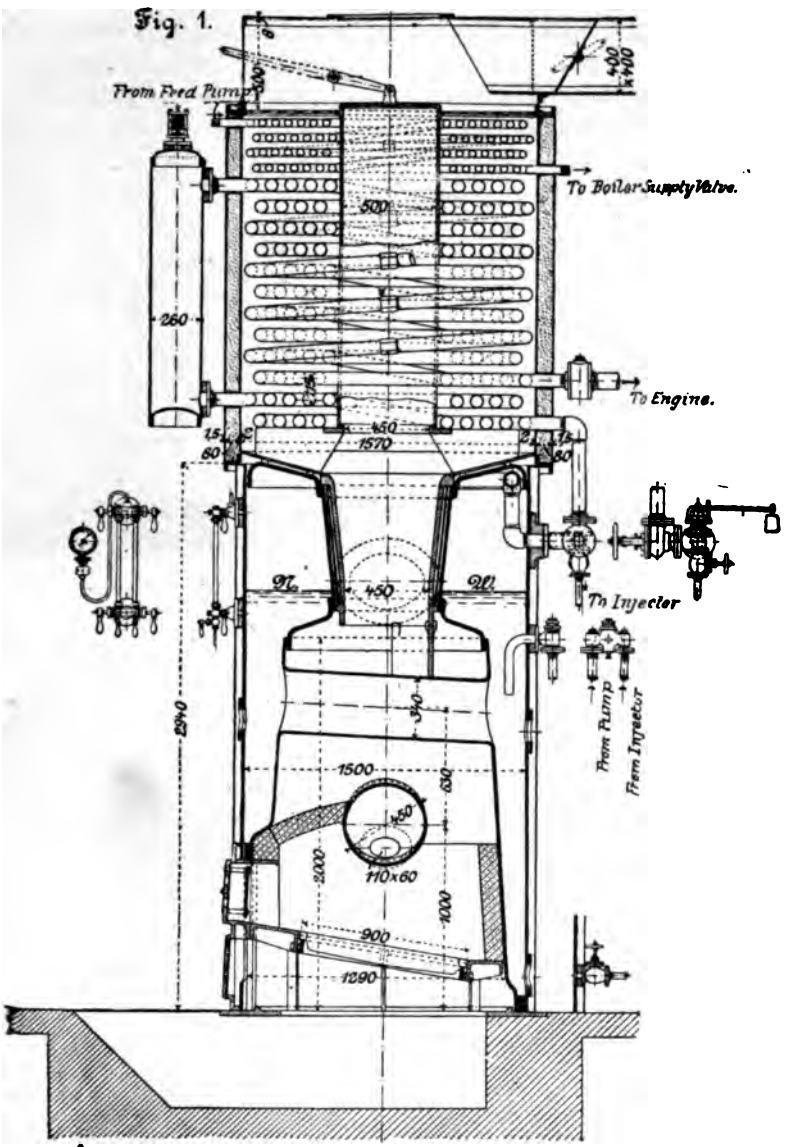
Geschaeftsberichte des Elsaessischen Vereins der Dampfkesselbesitzer, 1890–1894.

Reischle: Versuche mit Dampfueberhitzern, Zeitschr. Deutsch. Ingen., 1892 p. 505; 1894 p. 526.

Jahresberichte des Bayrischen Dampfkessel Revisions Vereins, 1893. Busley: Zeitschr. Deutsch. Ingen., 1888 p. 442.

inventor, Wm. Schmidt, C. E., of Wilhelmshoehe, a superheated steam engine. This engine attracted well deserved notice, not only because the result, which could have been arrived at only by

Fig. 1.



a gradual development, was boldly predicted by its inventor, and a temperature of 662° F. of superheated steam used; but, also, because entirely new and peculiar methods of construction were employed to secure a reliable and simple operation of the plant. The engine in question, built at Cassel,[2] is the first compound engine constructed under the Schmidt system.[3]

The boiler, [4] as shown in Figs. 1 to 4, is upright, and of the ordinary tubular form. On top of this is placed the super-

Fig. 2.

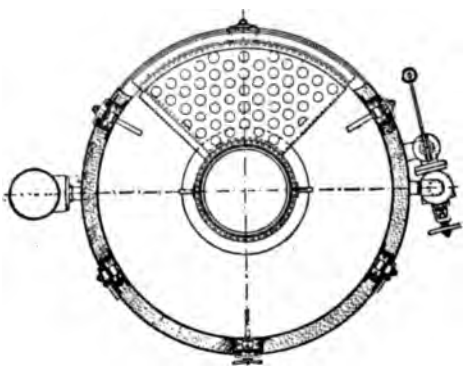


Fig. 3.

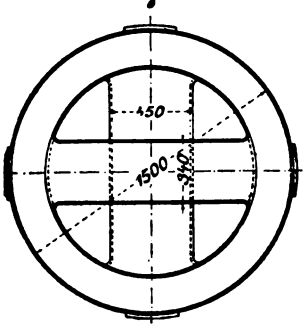
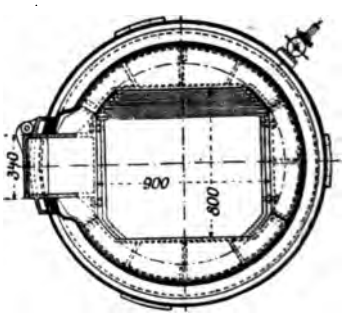


Fig. 4.



(2) In der Maschinenbaufabrik A-G, vormals Beck & Henkel. Zeitschr. Deutsch. Ingen., 1894—p. 1437.

(3) The first superheated steam engine has been in constant use for the past two years; in consequence of the good results obtained some sixteen firms have, in the meantime, secured the right for their manufacture.

(4) For a detailed description of the boiler, see Zeitschr. Deutsch. Ingen. 1889—p. 829; Journal of the International Alliance of Boiler Inspectors' Associations.

heater, consisting of wrought iron spiral tubes. The separate spirals are connected with each other by means of socket joints, and the spirals can be cleaned and renewed through doors placed in the surrounding shell. The two lowest spirals constitute the first superheater, into which the steam enters from the boiler at the bottom. The remainder of the spirals constitute the principal superheater, and this is connected to the first by means of a large vertical tube, known as the after-evaporator. The steam coming from the first superheater enters the after-evaporator at the bottom, and after passing up through it, circulates downward through the principal superheater, and from there passes through a check-valve to the engine.

The gases from the furnace may pass directly to the chimney through a flue in the centre of the spirals; when this is closed, however, by a trap, they must circulate about the tubes of the superheater in order to reach the chimney. When starting the furnace, the superheater is cut out entirely by means of the trap, which latter also serves to adjust the degree of superheating when the plant is running. In the present case, having to deal with water free from sediment, it was possible to place above the superheater a feed-water heater of similar construction.

The principle underlying the construction of this boiler is as follows: A comparatively small heating surface is employed (equal to 1 sq. ft. for 9 to 10 lbs. of water per hour), so as to obtain wet steam from the boiler. The tubes of the first superheater are exposed to the highest temperature of the gases; but these have to absorb a large quantity of heat to evaporate the water mixed with the steam, and are in this way guarded against too great a rise of temperature. This involves a sort of self-regulation; for, if the firing is very strong, the amount of water carried over with the steam will be large, and, consequently, a large amount of heat will be absorbed in the first superheater so as to evaporate this water. In this way, the danger of burning out the tubes is overcome.

From the first superheater the steam enters the large vertical tube, called the after-evaporator, for the reason that its object is to give the water in the mixture of saturated and superheated steam a chance to evaporate at the expense of the

Fig. 5.

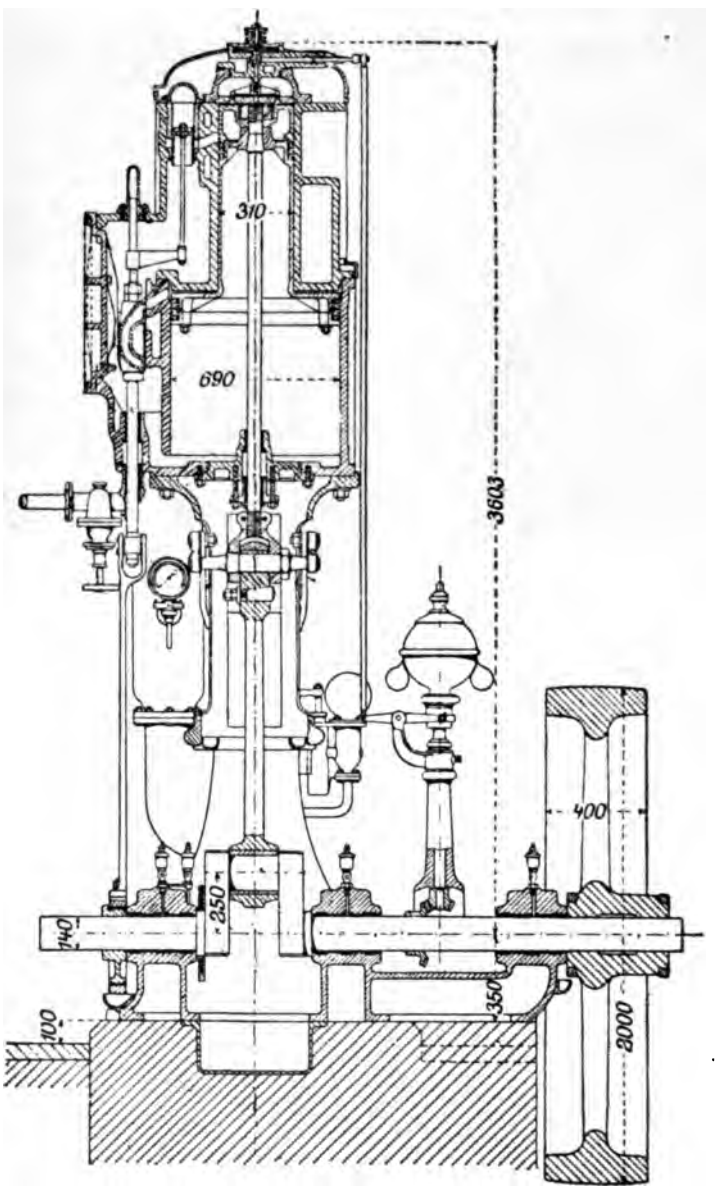
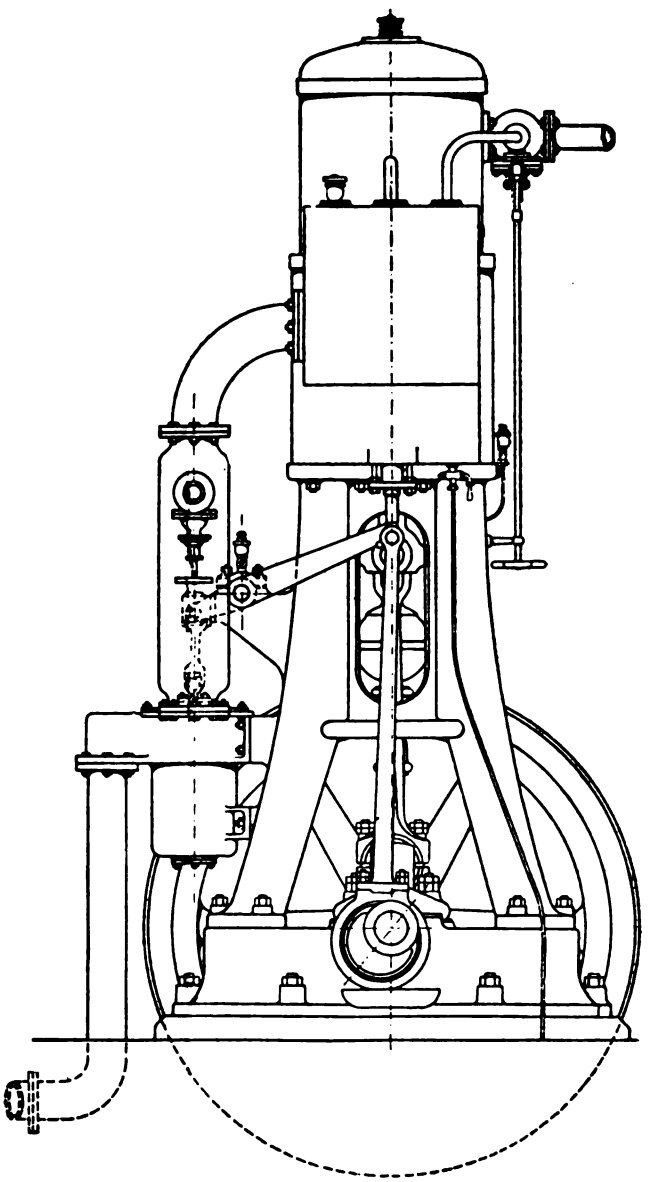


Fig. 6.



latter. That such an exchange does take place is shown by the fact that the temperature of the steam on leaving the tube is from 90 to 120 degrees lower than on entering.

The steam consequently enters the principal superheater at a temperature only slightly higher than that corresponding to its pressure, and at a point where the temperature of the gases is lowest. Inasmuch as the steam is flowing in the opposite direction to the gases it can easily leave at the bottom at a temperature of 662° F. without allowing the gases to enter the chimney at a higher temperature than 400° F.

The dimensions of the boiler are given in the following table:

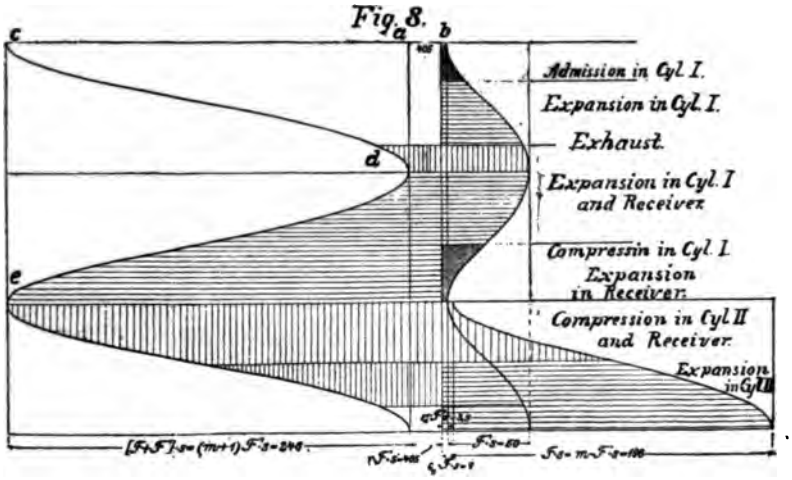
Total heating surface	96.0 sq. ft.
Not effective, owing to masonry	21.0 "
Effective heating surface	75.0 "
Heating surface of first superheater	64.6 "
" " " principal "	350.0 "
" " " feed-water heater	129.0 "
Grate surface	7.5 "
Steam pressure, gauge, lbs. sq. in.	170.0

The tubes forming the superheater are 2.36 inches inside diameter, and .197 inches thick; those forming the feed-water heater are 1.24 inches inside and .197 inches thick. The clear width of the boiler is 4.92 feet, and its total height is 17.39 feet. A good quality of hard coal was used for fuel; the composition of the coal as well as its calorific power is given further on. The water was fed by a pump operated by the engine itself.

The engine, shown in Figs. 5 and 6, is of the vertical tandem type, having two cylinders set one directly above the other without an intervening stuffing-box, and having a trunk-shaped differential piston, from which the motion is transmitted in the ordinary manner to the fly-wheel shaft placed below. The high-pressure cylinder is above, and the annular space below constitutes the low-pressure cylinder, both being single-acting. Instead, however, of placing the lower end of the piston in communication with the atmosphere, the low cylinder is closed by a cylinder head with a stuffing-box, and a space is thus gained which

serves the double purpose of a receiver and of a third and larger cylinder, whose volume is equal to that swept through by the largest face of the piston. In the high- and low-pressure cylinders the steam presses downward on the piston, while this pressure acts upward in the receiver. When the piston descends there is, during admission and expansion, a higher pressure in the high cylinder than in the receiver, consequently producing a resultant downward pressure on the piston; in the low cylinder there is, during admission, receiver pressure on both sides of the piston, while during expansion the upward pressure is increasing, and becomes equal to the pressure in the high cylinder just before the dead point. At this point the high cylinder is placed in communication with the receiver, and the low

Fig. 8.



cylinder with the condenser. When the piston rises there is, therefore, equal pressure on both sides of the high cylinder piston, while there is vacuum on the upper face of the low piston and receiver pressure below it, so that a resultant upward pressure acts during the ascent of the piston. In this way a double action is secured which helps the uniformity of the motion. That the receiver gives a diagram of positive work, which must be added to the other diagrams as that of a third cylinder, is shown in Fig. 8, in which the three sinusoids represent the

variations in volume of the three acting surfaces of the piston; this diagram will be explained more fully further on. The engine is, in fact, a three-cylinder engine, only not in the usual sense, for the expansions do not take place consecutively in the three cylinders, and the cylinder which connects with the condenser is intermediate in size.

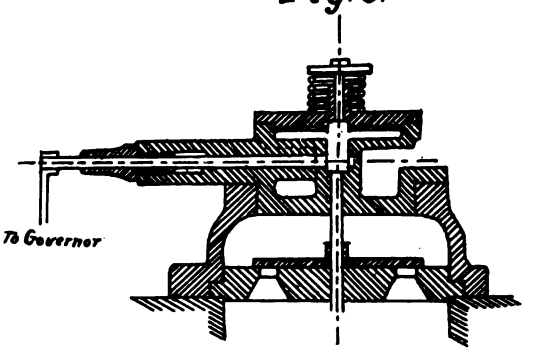
The receiver consists of two parts, one of constant and the other of variable volume; the volume of the first is represented by a–b in Fig. 8, being drawn on a much smaller scale than the other volumes. The abscissas of the sinusoid c–d–e give the volumes of the variable part. At the upper dead point this volume equals the sum of the volumes of the high and low cylinders and it becomes zero at the lower dead point. If no steam were added or taken away from the receiver the work of compression on descending would exactly equal the work of expansion on rising; but, since steam is taken away to fill the low cylinder when the piston descends, and steam comes in from the high cylinder when it rises, a higher mean upward than downward pressure is obtained, and positive work is done in the receiver.

This work is inversely proportional to the volume of the receiver, and becomes zero for an infinite volume. In the present case, a large receiver is employed, its greatest volume being 3.31 and its least 2.06 times the volume of the large cylinder. The work done in it is therefore small; for it is not necessary to divide the range of temperature among the three cylinders, as the highly superheated steam may fall considerably in temperature without loss by condensation, and the low cylinder is amply heated by the steam in the surrounding receiver. Not only are the cylinder head and piston heated, but the cylinder walls themselves are heated by contact with receiver steam just before the low-pressure steam enters the cylinder.

The low-pressure cylinder is controlled by a slide valve of the ordinary form, from which the motion for the exhaust of the high cylinder is obtained. For the admission of the high cylinder a valve is used which is automatic in its action, and whose throw is varied by a governor. This peculiar apparatus is shown in Fig. 9. High-pressure steam presses down on the valve; and a spring, together with the pressure of the com—

pressed steam in the clearance space, press upward, tending to open the valve. When the upward exceeds the downward pressure, the valve is opened an amount which depends upon the particular position of the governor. A change in the latter produces a corresponding change in the throw of the valve, by means of an intervening cam, as may be seen from the figure.

Fig. 9.



As long as the pressure above and below the valve is about equal, it will remain open; but, when the piston descends and steam rushes through the valve, there results an excess of downward steam pressure, which increases as the piston speed increases, and, finally, overcomes the tension of the spring and closes the valve. If the throw of the valve is great this will occur late, for a high piston speed will be required to produce a sufficient velocity of steam to overcome the tension of the spring. The work done by the governors is small, having only to turn a spindle carrying the cam, the use of an air dash pot preventing too sudden motion of the valve.

When starting the engine, the cylinder walls are cold, and the pressure of the compression may not be sufficient to open the valve. In this event the piston strikes a projecting pin just before the dead point, which opens the valve and secures the starting of the engine. This peculiar controlling mechanism works perfectly, and the diagrams to be considered later will show that the distribution of the steam is all that can be desired; the fact that throttling during admission takes place,

owing to the action of the valve, can well be neglected when we consider the economical working of the machine.

This very simple admission valve is, without doubt, a solution of the problem which, particularly for superheated steam, could not be more suitable. The inventor has applied this valve with equal success to the high cylinders of compound engines and to operate the exhaust of non-condensing engines.

The condenser consists of cast-iron pipes, over which the water falls cascade-like. The vacuum pump is of the vertical type and single-acting, having a cylinder 11 inches diameter and 6.4 inches stroke, the valves being of rubber.

The general dimensions of the engine are given in the following table :

	Cylinder 1.	*Cylinder 2.*	*Receiver.*
Diam. of piston, in	12.3	27.1	....
Net piston area, sq. in	117.74	461.85	....
Stroke, ft	1.64	1.64	....
Net volume of cylinder, cu. ft.	1.34	5.26	....
Clearance, per ct	7.0	3.56	....
Least volume at lower dead point (constant), cu. ft	....	....	10.86
Net volume swept through by large piston, cu. ft	....	....	6.55
Greatest volume at upper dead point, cu. ft	....	....	17.41
Ratio of net working volumes	1.0	3.92	4.88

The object of the test was primarily to measure the coal used per hour per brake H. P., which had been guaranteed not to exceed 1.79 lbs.; the water consumption per I. H. P. was also measured. The engine was new, having been put into operation but a few days before making the test. Two tests were made at the works of Beck & Henkel, Cassel, with the aid of two assistants, and under conditions considered to be normal. No interruptions of any kind occurred during the tests. All precautions were taken to secure the highest degree of accuracy obtainable in a test of this kind. The indicator springs were tested at the Laboratorium fuer Maschinenlehre in Munich, and the thermometers were compared with a standard from the Physikalisch-Technischen Reichssanstalt. The chimney gases were analysed by an engineer experienced in this work.

The effective work was measured by means of a Prony brake attached to the rim of the fly-wheel, equilibrium being readily maintained by means of a scale, as sufficient cooling water was at hand. The results follow:

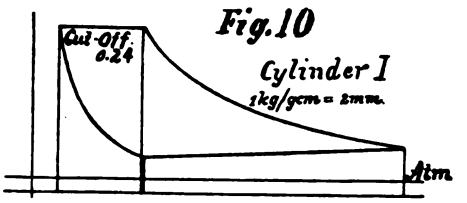
Date.	Duration of test.	Average rev. per minute.	Brake weight, lbs.	Brake H. P.
July 28	6 h. 6 m.	116.3	245.8	61.7
" 30	7 h. 44 m.	117.3	245.8	62.2

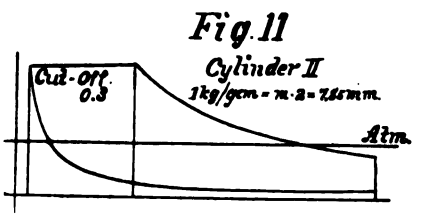
The peculiar action of the engine makes it desirable to consider the form of indicator diagrams to be expected. Figures 10 to 17 show these diagrams; one set is constructed assuming that release does not occur in the high cylinder before the end of the stroke, and that no fall of pressure exists between the two cylinders. The other set assumes release to occur before the end of the stroke and a fall in pressure between the cylinders. The combined diagram[1] for each case is also constructed. The curves of piston displacements are shown in Figure 8, three strokes being represented. The phases of the steam distribution will be understood from the notes on the figure. Expansion is represented by horizontal, and compression by vertical, shading.

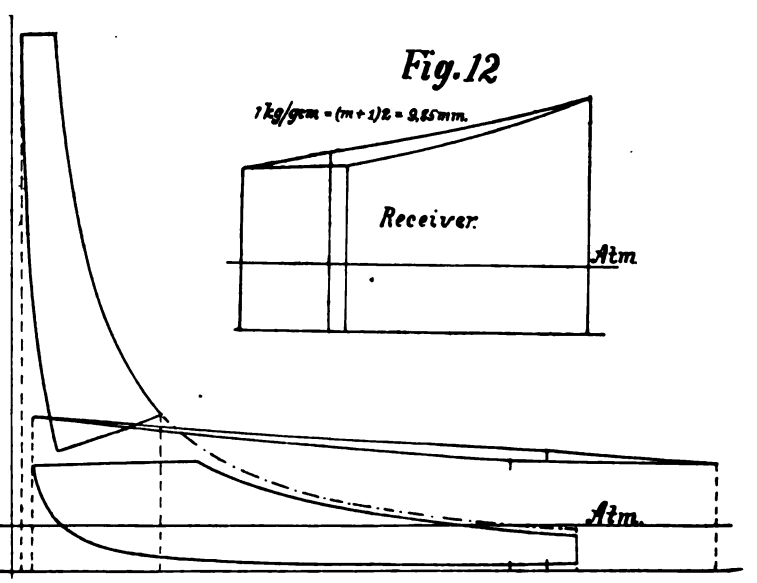
Both groups of diagrams have hyperbolas for expansion and compression lines, the scales for pressures for the various diagrams being proportional to the respective volumes, so that the areas of the cards are as the work done in the respective cylinders. In the diagrams with drop in pressures, the cut-off is reduced to the admission line, so as to afford a comparison with actual cards. Of the latter, one set for each test is reproduced in Figures 18 to 25, and the combined diagrams are constructed. By inspection these are seen to agree in form with the theoretical cards, excepting, of course, the throttling during admission and rounding of corners. The admission line of the high cylinder shows the peculiar effect of the automatic valve. The even run of M. E. P. in the different diagrams shows that at constant speed the cut-off is also nearly constant. The occasional action of the governor is seen from the curves in Figs. 26 and 27. The latter diagram was run over twenty times, and it is seen

(1) For method of combining see Zeitschr. Deutsch. Ing. 1884, p. 191; 1890, p. 553.

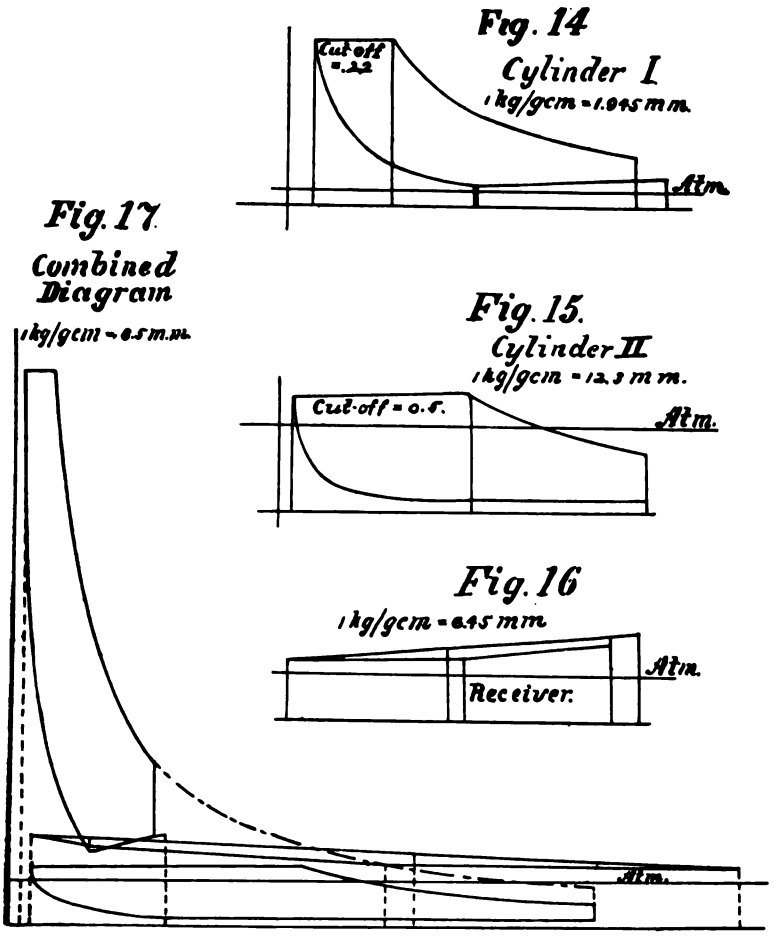
that the curves do not overlap, which is due to small variations in the positions of the governor; but the effect does not extend beyond the expansion period of the high cylinder. The governor should have been provided with a suitable oil dash pot.







Diagrams with no fall in pressure.



The indicated work was as follows:

	July 28.			July 30.		
	Cyl. 1.	Cyl. 2.	Receiver.	Cyl. 1.	Cyl. 2.	Receiver
M. E. P., lbs. per sq. in.	68.0	8.34	.89	68.5	8.9	.31
Average revolutions..	....	116.3	....	....	117.3	....
I. H. P.....	46.1	22.2	2.95	47.0	24.0	4.37
Total I. H. P.....		71.25			75.37	
Brake H. P.....		61.70			62.20	
Difference.....		9.55			13.17	
B. H. P. ÷ I. H. P..		0.865			0.826	

The increased friction on the second day is believed to have been caused by a small amount of sand which was found around the high cylinder piston. In a new machine the friction is not a fixed quantity, but one which decreases with time. It will undoubtedly reach a satisfactory value for the machine in question.

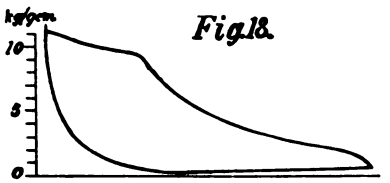


Fig.18.

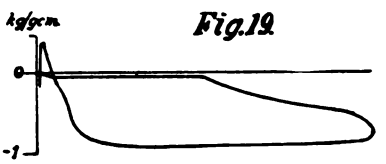


Fig.19.

Fig.20.

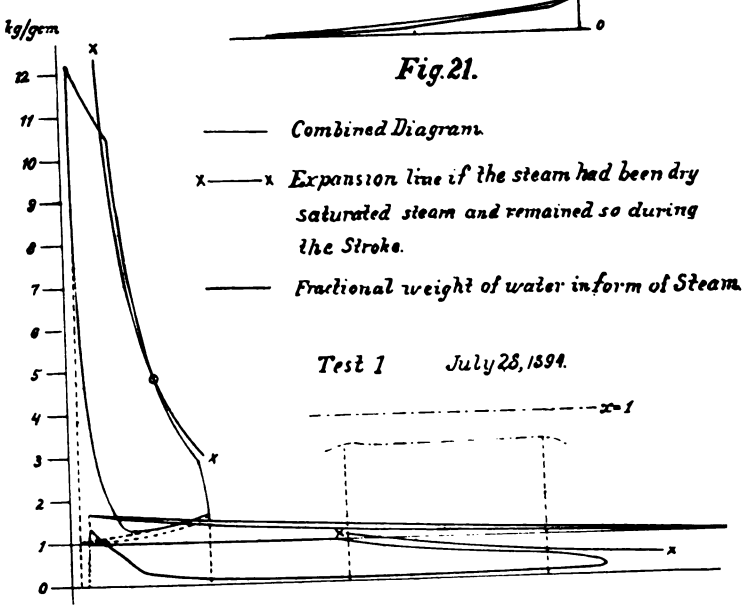


Fig.21.

——— *Combined Diagram.*

x——x *Expansion line if the steam had been dry saturated steam and remained so during the Stroke.*

——— *Fractional weight of water in form of Steam.*

Test 1 *July 28, 1894.*

From the diagrams we get an average ratio of the absolute pressures at the beginning of expansion and admission, = 0.79; the loss of area due to throttling being 8%.

The water consumption was made the subject of very careful measurement; the water being weighed directly, and the load kept uniform, so that the water used per hour varied but little. The temperature of the feed water was measured by means of a thermometer placed in a cup containing oil, this cup being inserted into the feed pipe, and all surrounded with a heavy coating of wadding. In this way only a very slight error was possible.

The following table gives the results :

	July 28.	July 30.
Total feed water used.....lbs....	4740.0	5924.0
Duration of test.....hs.....	6.1	7.73
Feed water per hour..... lbs....	777.0	766.0
Average temp. feed water, initial.....	79°F.	86°F.
" " " " terminal.....	190°F.	194°F.
Water per hour per brake H. P.....lbs....	12.6	12.3
" " " " I. H. P..... "	10.9	10.16
Boiler pressure, gauge, lbs. sq. in.....	168.0	170.0
Initial pressure in diagram, gauge, lbs. sq. in.....	156.0	159.0

This is the first time that any steam engine has ever given such a low figure for the water consumption, and is a proof of the correctness of the assumptions made by Mr. Schmidt. The smoothness of running during the test is evidence of the judicious methods employed in the construction.

Before entering upon theoretical considerations, it will be well to examine the distribution of temperatures which play such an important part in this machine. From the curves shown in Figs. 28 and 29 it is seen that different degrees of superheating were employed in the two tests. The temperature of entering steam was quite uniform, although the fluctuations in the temperature of the furnace gases were considerable. That the heat was well utilized is shown by the low temperature at which the gases entered the chimney, as well as by the large per cent. of CO_2 found by analysis.

The temperature of the gases at the first superheater was

measured by a pyrometer whose error could not be determined, so that only the relative values are to be considered. The steam temperatures were measured by standardized thermometers, while a corrected pyrometer was used for the chimney gases.

The following table gives the average values :

Date.	Steam Temperatures.					Temperatures of Furnace Gases.	
	After-Evaporator.		Leaving Boiler.	Entering Engine.	Corresp'd'g Temp. of Saturation.	At First Superheater.	In Chimney.
	Entering.	Leaving.					
	Deg. Fahr.	Deg. Fahr.	Deg. Fahr.	Deg. Fahr.	Deg. Fahr.	Deg. Fahr.	D. F.
July 28th....	....	452	662	605	373.8	1211	358
" 30th....	592	525	675	650	374.0	1292	357

*Thermometer damaged.

The decrease in the fall of temperature between engine and boiler on the second day was due to improved jacketing of the steam pipes. This point is one of eminent importance in the application of superheated steam, for, with long steam pipes, the entire success may be threatened by neglect of proper jacketing. Even with saturated steam this point can effect a far greater saving than is generally recognized The initial temperature of the steam in the high cylinder has an important influence on the economy. The writer believes that the decrease in the weight of water used per hour on the second day is entirely due to the increase in the degree of superheating. That the temperature of the chimney gases is less than that of the saturated steam is explained by the presence of the feed-water heater.

The chimney gases were analyzed by Mr. Wedekind, using the apparatus of Orsat-Fischer. The samples were taken near the first superheater at intervals of 10 to 15 minutes by means of a porcelain tube inserted for that purpose. The following table gives the results of the analysis, and shows that the combustion was excellent.

The percentage of CO_2 shows that the excess of air admitted was small. The first test indicated that the grate surface was

ANALYSIS OF CHIMNEY GASES.

	July 28.				July 30.			
	Per Cent.			Remarks.	Per Cent.			Remarks.
	CO_2	O	CO		CO_2	O	CO	
1	15,4	1,0	0,8		16.6	1,8	0.0	
2	15.2	1,4	1,6		11.6	4.8	—	
3	15.9	3.4	—		13.2	5.2	—	
4	14,2	2,6	—		10.0	3.0	5,8	
5	15.8	4,0	—		13.4	3.4	—	
6	4.0	10,2	5,0	Directly	13.2	3.6	—	
7	16.8	2.0	—	after	11.0	4.0	1.0	
8	16,2	2.2	0.0	starting fire.	15.6	2,4	—	
9	15,0	2.4	—		13,4	2,4	—	
10	16,0	2,6	—		16,0	1.4	0,2	
11	13.2	5.2	0,4		16,2	1.8	—	
12	15.0	3,8	—		15.2	2,6	—	
13	14,4	3.8	0.3		16.4	1.6	0,0	
14	12,0	4,2	—		14.2	1.6	—	
15	13,0	4,4	—		16.6	2.4	—	
16	9,6	6,6	—		16,2	2.6	0.0	
17	12,0	4,5	—		15.0	2.2	—	
18	10.2	5,3	—		15.2	2.8	—	
19	10,0	—	—		16.2	2.6	—	Average Chimney
20	13,0	—	—	Porcelain	14.2	4,0	—	Draught
21	13.0	—	—	Tube	14.0	2,6	—	7 mm. water.
22	11,0	—	—	damaged.	12.6	6,6	—	
23	10,0	—	—		14.2	4.2	—	
24	12.4	4.6	0.2		13.0	1.4	1.8	
25	15,0	2,2	—		16,0	1.8		
26	14.2	3,4	0,0		15,2	2.6	—	
27	13,5	4,2	0.8		15.8	2.0	0.0	
28	15.0	2,6	—		17,4	1.4	—	
29	14.0	4,0	—	Average Chimney	13,8	5.0		
30	14,8	3,2	0,0	Draft	13,2	6,4	—	
31				6 mm. water.	15.0	3.4	0,0	
32					14.8	1.6	—	
33					12.2	6.8	0,0	
34					16.6	2.2		
35					15,8	1.8	—	
36					13,4	2.0	1.4	
37					16.6	3.0	—	
38					15.6	1,4		
39					16,6	1,8	0,0	

too large. It was therefore reduced before making the second test, and a slight gain in the evaporation was effected.

At each weighing (of 25 kg.), a small amount of the coal was laid aside, so as to obtain an average sample. This, together with some of the ash, was sent to the Grossherzogl. Chemische-Technische Pruefungs und Versuchsanstalt in Karlsruhe to be analyzed.

The following is an abstract of the results:

		July 28.	July 30.
Carbon	%	79.37	79.42
Hydrogen	"	3.31	3.71
Oxygen and nitrogen	"	13.69	11.79
Sulphur	"	0.98	1.09
Ash	"	1.97	2.87
Water	"	0.68	1.12
		100.00	100.00

The calorific value is given by the formula

$$8100.\ C + 29000\ (H - \frac{O}{8}) + 2500\,S - 600\,W = \text{calories per kilog.}$$

The actual values were found by means of a Mahler calorimeter and these were used in the calculations.

CALORIFIC VALUE OF THE COAL.

	Test 1.	Test 2.
B. T. U. per pound, calculated	12443	12785.
B. T. U. " actual	12573	12877.

The analysis of the ash gave the following results:

		Test 1.	Test 2.
Pure ash	%	44.26	49.22
Combustibles	"	55.06	49.89
Water	"	0.68	0.89
		100.00	100.00

The observations and calculated results are as follows:

		Test 1.	Test 2.
Total weight of coal used, exclusive of fuel for starting fire	lbs	601.00	747.00
Coal used per hour	"	98.50	96.60
Per cent. of ash and slag	"	11.40	14.20
Feed water per hour	"	777.00	766.00
Evaporation in lbs., per lb. of coal actual		7.88	7.93

Evaporation in lbs., per lb. of coal at atmospheric p. and feed water, 32° F..	8.65.....	8.82
Coal consumption per brake H. P. hour, lbs.	1.60.....	1.55
" " " I. H. P. " ".	1.38.....	1.28

The average coal per hour per brake H. P. is therefore = 1.57 lbs. under constant load.

An analysis of the manner in which the heat of the coal is utilized by the boiler proves that the high degree of superheating was not alone of advantage to the engine, but that the steam is also generated in a thoroughly economical manner. The temperature of the feed water was first increased about 110 degrees at the expense of the heat in the escaping gases. It was then converted into saturated steam, and, finally, superheated under constant pressure to 662° and 675° F. in the respective tests.

The heat required for this per pound of coal is :

$$Q = w[t_2 - t_1 + h_2 + .48\ (t_3 - t_2)]$$

in which w = no. lbs. of water evaporated.

This gives :

Per pound of coal		Test 1.	Test 2.
To heat feed water.....	B. T. U.,	874	856
To evaporate water	"	8176	8199
To superheat.....	"	872	1053
Total heat accounted for.....	"	9922	10108

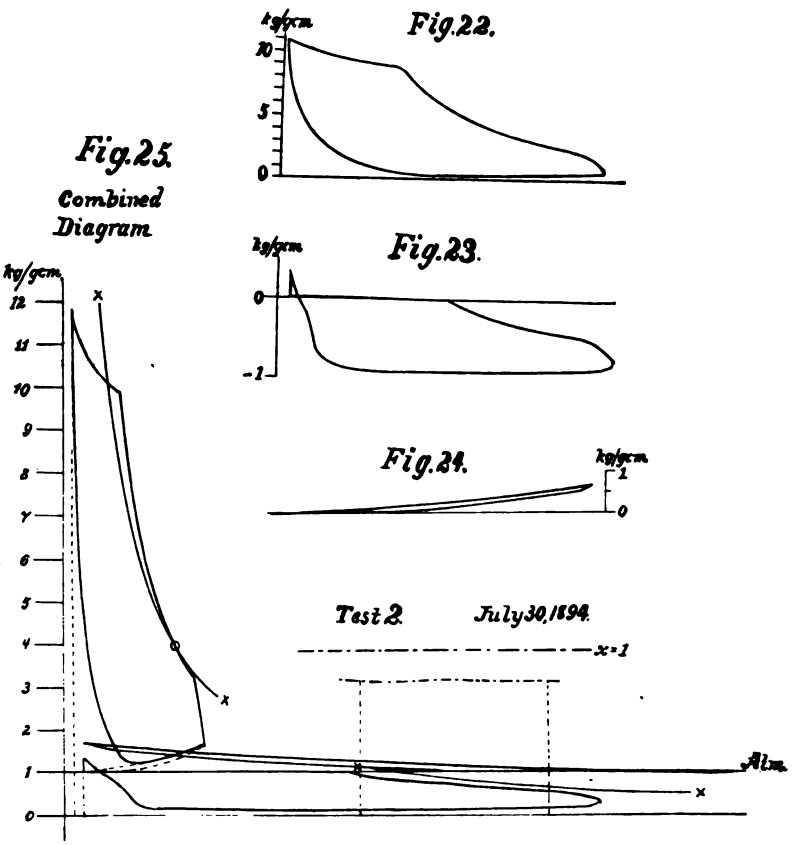
Absolute per cent. of heat utilized:		Test 1.	Test 2.
To heat feed water.....	Per cent.,	65.0	63.7
To evaporate feed water.....	"	6.9	8.2
To superheat feed water.....	"	6.9	6.6
	"	78.8	78.5

Dividing finally the B. T. U. accounted for by the latent heat of steam at 212° F., we get the evaporation of the boiler per pound of coal from and at 212° F.

Test 1— 9922 ÷ 966 = 10.2 } = { Evaporation in pounds,
" 2—10108 ÷ 966 = 10.4 } = { from and at 212° F.

A study of the behavior of the steam in the engine is of no less interest than the preceding investigation ; and for this purpose the indicator diagrams afford the necessary bases, such diagrams being chosen from each test as were most nearly equal

in area to the average for the test. The object is not, however, to study whether the indicated work might not have been larger with some other cut-off in the L. P. cylinder—that would require another series of experiments. What is desired, is to study the condition of the steam during its passage through the engine. For this purpose it is only necessary to compare



the volume of the working weight of steam at every position of the stroke with the volume of the same weight of saturated steam under like pressure. This is accomplished by constructing the saturation curve, as shown in Figures 21 and 25. The details of the calculations for the first test are given in what follows.

The initial pressure of admission, as found from the sample diagram, is 173.5 lbs. per sq. in. absolute; the feed water supplied to the boiler for each diagram is $\frac{777}{60 \times 116.3} = 0.111$ lbs. This weight could be used directly if all the cards had the same cut-off. The average value of the latter is 0.327, while that of the sample card is 0.316, so that the weight of steam actually used for this diagram is very nearly $0.111 \times \frac{316}{327} =$ 0.1076 lbs. From steam tables we find 0.28 cu. ft. for the volume of this weight of saturated steam.

It remains now to determine the condition of the compressed steam in the clearance space when the admission valve opens. Exact information cannot be obtained on this point; and the assumption usually made, that the compressed steam is just saturated, must be adopted here. The further assumption, that the steam is at every instant a homogeneous body, whose changes are given by the diagram, must also be made; for, without this, no calculations would be possible. We have:

Volume of clearance space	0.093 cu. ft.
Volume of steam admitted	0.280 "
Total	0.373 "

which is $\frac{0.373 \times 100}{5.26} = 7.1\%$ of the volume of the low cylinder.

From this data the saturation curve can be constructed to the proper scale on the diagram, as in Figures 21 to 25.

An exactly similar calculation for the second test gives the following results:

Initial steam pressure, lbs. per sq. in. absolute	169.0
Average weight of steam per diagram, lbs.	0.109
Average cut-off, %	34.86
Cut-off in sample card, %	37.2
Weight of steam for sample card, lbs	0.116
Volume of this weight of saturated steam, cu. ft.	0.311
Volume of clearance space, cu. ft.	0.094
Total volume, cu. ft.	0.405

This volume in per cent. of volume of large cylinder, % 7.7

In both cards we find that the saturation curve intersects the expansion line of the high cylinder diagram. This is an important fact, for it shows that the steam reaches the saturation point during expansion in the high cylinder (always considering the steam to be a perfectly homogeneous body). In the second test a higher degree of superheating was

Fig. 26. Fig. 27.

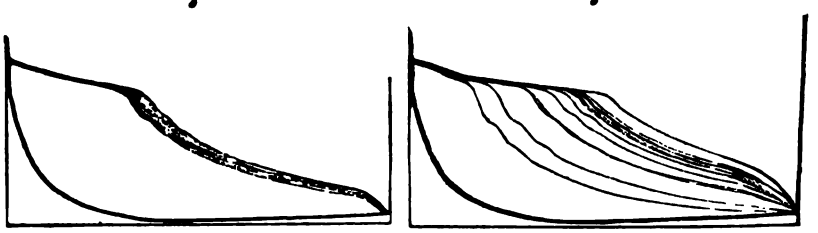
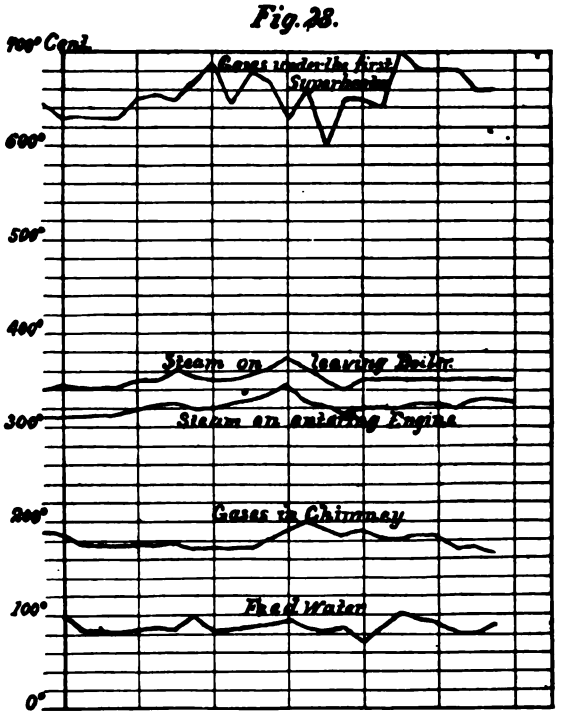
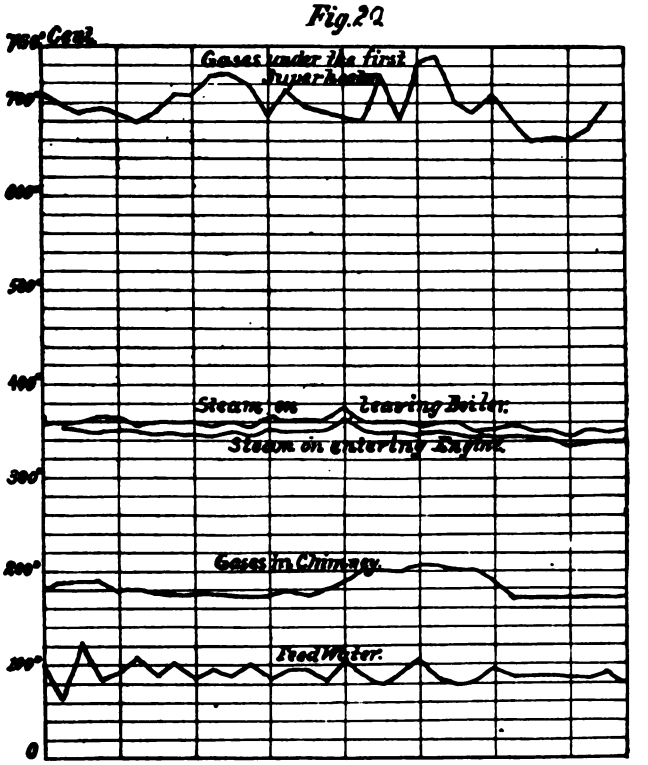


Fig. 28.



Temperature Curves.
Test I

Fig. 22



Temperature Curves

Test II.

employed, and consequently, this point is found nearer the end of the stroke.

For the sake of completeness, the same calculations were made for the large cylinder, and the curve of saturation constructed as before.

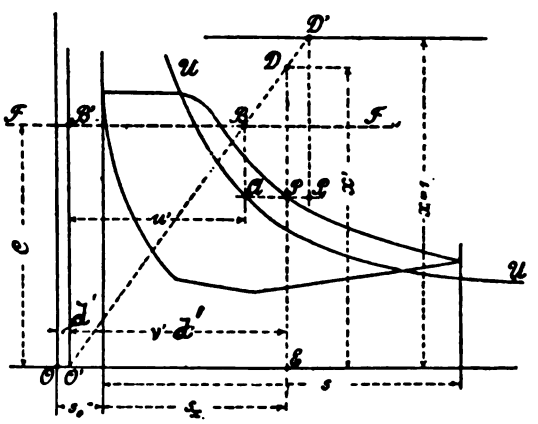
The results are as follows :—

	Test 1.	Test 2.
Steam pressure during admission in lbs. per Sq. in. absolute	14.20	14.20
Volume of steam admitted, cubic ft	2.94	3.16
" " clearance space, " "	0.187	0.187
Total volume, " "	3.12	3.35
This volume in per ct. of low cylinder	59.5	63.6

Since the saturation curve for the low cylinder diagram falls entirely outside of the actual expansion line, it follows that the steam in this cylinder is saturated and mixed with water throughout the expansion.

In the diagrams of Figs. 21-25 two curves are drawn giving x, the fractional weight of the water in the form of vapor, for the expansion period of the low cylinder. A simple graphical method, illustrated in Fig. 30, was used to construct this curve; the explanation of the method is as follows: Let G = weight of steam admitted (calculated from water consumption); G_0 =

Fig. 30



weight of steam saved in clearance space (calculated from volume of clearance space and density of saturated steam at terminal pressure of compression); S_0 = length of clearance space in diagram; S_x = length of stroke to any point in expansion line; p = abs. pressure, and y = density of steam at this point; F = area of piston. Then the fractional weight of water in the form of vapor will be

$$X = F\frac{(S_x + S_0)y}{G + G_0}$$

for a point P on the diagram (Fig. 30); but we also have

$$v = x\,u + d$$

which is the fractional volume of the saturated steam, if

$$u = s - d$$

that is, equal to the difference between the volumes of dry saturated steam and water.

This formula may be written

$$x\ u = v - d$$

and, if the values of x, u and (v–d) be represented by lengths x′, u′ and (v′–d′) the scales used may be included in a single constant, and we have

$$x'\ u' = C\ (v' - d')$$

The scale for v is to be so chosen that its value is represented by the abscissa of the expansion line. The volumes (v′–d′) must then be measured from a vertical through O′ drawn at a distance d′ from the axis. In general this distance is too small to be represented on the drawing; but the volumes of the clearance spaces cannot be determined with much accuracy, so that this approximation is justified. The values of u, found from a steam table, are represented by lengths u′, and are laid off from O′B′ on the line of the corresponding pressure; the points so obtained form the curve u–u. Draw also a horizontal line FF, at a distance C from the volume axis, for which purpose C may be calculated from the assumed scales. Assume, now, that C is known; then to fix x′ for any point P of the diagram, project P on the curve of u–u, as A, from the revertically to B on the line FF, and connect B with O′; the line B–O′ will cut from the ordinate through P a length, equal to the desired value x′. For, from the figure,

$$D\ E : E\ O' = C : B\ B'$$

or

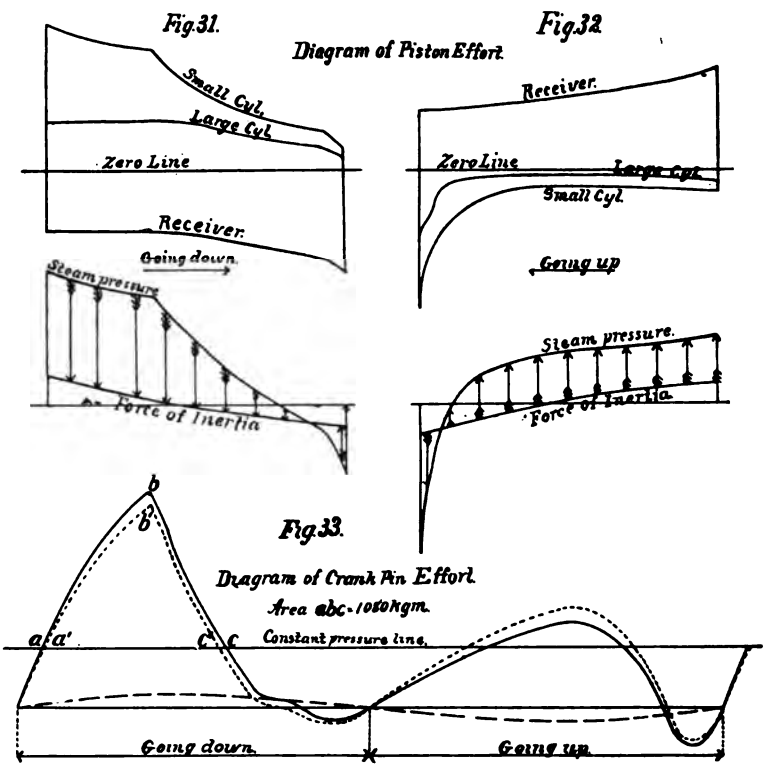
$$x' : (v' - d') = C : u'$$

The co-ordinates of the line O′ D give the values of (v–d) and x corresponding to the pressure P and the working weight of steam $(G + G_0)$. For instance, when x = 1, the projection of D′ on the horizontal through P will give a point P_1, through which the expansion line would pass if there were no water in the cylinder. By this method it is therefore easy to construct curves for constant weights of steam. Taking any value of x, draw a corresponding horizontal line, and project its intersection with O′ B on the proper pressure line of the diagram. For suitable scales may be used: u′ = 200. u mm and x′ = 100 x. mm, so that x = 1 is represented by a horizontal line drawn at a distance of 100 mm, above the axis. If this construction

is continued beyond the beginning and the end of expansion, then the curve will suddenly change in curvature, owing to the different weight of steam then in the cylinder. This may serve to indicate the position of cut-off and release in the diagram.[1]

In this way, the curve of x has been constructed for the sample low cylinder diagram of each test. An examination of these curves shows that about 84% of the water is in the form of steam.

The behavior of the steam in the two cylinders indicates that the principal reason for the remarkably low water consumption of this engine is the elimination of all initial condensation in



(1). S. Schweizerische Bauzeitung, 1881, Prof. Fliegner: Die Bestimmung der Hauptpunkte eines Indikatordiagrammes.

the high cylinder. The whole design has, in fact, been carried out with the idea of avoiding cylinder condensation by a constant heating of the cylinder walls with receiver steam. The writer believes that, with a different arrangement, even more might be accomplished; for the results show that a considerable exchange of heat takes place between the steam and walls of the low cylinder. Perhaps radiation is also an important element. By far too little has as yet been done in practice to avoid this loss.

It was, finally, of importance to determine the fluctuations of speed, for which purpose the diagrams of piston effort were constructed (Figs. 31 and 32). The weights of the reciprocating parts act as positive forces when the piston descends, and as negative forces when it ascends. The effects of acceleration and retardation of these masses were also determined, and are illustrated in the figure. The diagram of crank pin effort, Fig. 33, is constructed in the usual way; the dotted line being first drawn. The broken curve a′ b′ c′ gives the tangential effects of the weights of the moving parts. These components are added to the crank pin efforts for the downward, and are subtracted for the upward motion; and the resultant curve, a b c, of crank pin efforts is thus constructed. This is necessary, since the weights are not balanced. By means of a planimeter, the mean effort is found. The weight of the fly-wheel being also known, the coefficient of fluctuation of speed was calculated and found

$$\delta = \frac{1}{32.5}$$

and, if the weights of the moving parts had been balanced (dotted curves), then

$$\delta = \frac{1}{37.8}$$

showing that 16% could be gained by balancing; otherwise a second fly-wheel might be added, or the first one made larger if this should become necessary, thus decreasing this coefficient by any desired amount.

Looking over the results obtained by this new compound engine, one must admire the simplicity with which the inventor put his ideas into practical form, and thus gave an impulse to

engine building, of which the effect cannot be, as yet, foreseen. It is all the more important, because the triple expansion engines, constructed by the leading makers of to-day, have already reached a high degree of perfection, while this new engine is the first of its class, so that a still further development of this new idea will undoubtedly lead to results still more remarkable.

DISCOVERY OF HELIUM IN A TERRESTRIAL MINERAL (CLÈVEITE) BY PROF. W. RAMSAY.

In a recent number of the London *Chemical News* (March 29th, p. 151) we notice the announcement of what is indicated in the above title, together with observations on the spectrum of the new element, by Dr. Wm. Crookes.

"Chemical analysis of the substances composing the earth's crust has thus far revealed nearly seventy distinct elements; and spectroscopic study of the sun has already detected the presence of more than half of them in that body. But there are indications that the sun contains a few elements which are yet unrecognized in terrestrial matter. For instance, there is a line in the green part of the spectrum of the outermost solar envelope, the corona, which is thought to represent a gas much lighter than hydrogen. The line itself is numbered 1,474 in the old Kirchhoff scale, but in Rowland's, which is the modern standard, it is set down at 5,316. The substance itself is called 'coronium.' Nothing of the sort has been found on the earth. Again, when the spectroscopists examine the chromosphere, the layer of gas next below the corona, but lying above the luminous cloud-shell of the sun, they discover in the yellow a brilliant line, which they used to call 'D3,' but which is situated at 5,876 in Rowland's scale. No line could be perceived at this point in the spectrum of any terrestrial substance, and hence the element thus signified was, like coronium, regarded as peculiar to the sun. Indeed, such a supposition is embodied in its name, 'helium.' Since the first discovery of the D3 line, however, the latter has been recognized in the spectra of a few stars, which are also suns, but many million times as far away from us as our own."

Now, however, Prof. Ramsay, who was associated with Lord Rayleigh in the discovery of Argon, announces that he has obtained from the mineral Clèveite a gas whose spectrum corresponds with the Helium lines in the solar spectrum, and also contains the distinctive lines of Argon. It would therefore appear that this gas extracted from Clèveite by boiling with weak sulphuric acid is a mixture of Argon with the element causing the Helium lines in the solar spectrum. There are, however, some violet lines in the Argon obtained from the atmosphere which are not found in the gas from Clèveite, so that there are probably at least three new elements here to be considered, 1st, the part of Argon common to the atmosphere and to Clèveite; 2d, Helium, and 3d, the part of Argon found only in the atmosphere. H. M.

STANDARDS FOR ELECTRICAL MEASURE.

In July, 1894, an act of Congress was passed to define and establish the units of electrical measure. By this law, Congress made it the duty of the National Academy of Sciences to prescribe and publish specifications necessary for the practical application of the definitions of certain units of electrical measure adopted in the act. The National Academy of Sciences appointed as a special committee to consider the subject:

Prof. H. A. ROWLAND, *Chairman*, Johns Hopkins University, Baltimore.
Gen. H. L. ABBOT, United States Engineers, New York.
Prof. G. F. BARKER, University of Pennsylvania, Philadelphia.
Prof. J. TROWBRIDGE, Harvard University, Cambridge.
Prof. C. S. HASTINGS, Yale University, New Haven.
Dr. C. BARUS, Smithsonian Institution, Washington.
Prof. A. A. MICHELSON, University of Chicago, Chicago.

The committee completed the work assigned to them, and reported the following:

SPECIFICATIONS FOR THE PRACTICAL APPLICATION OF THE DEFINITIONS OF THE AMPERE AND VOLT.

SPECIFICATION A.—*The Ampere.*

In employing the silver voltameter to measure currents of about one ampere, the following arrangements shall be adopted:

The kathode on which the silver is to be deposited shall take the form of a platinum bowl not less than 10 centimeters in diameter, and from 4 to 5 centimeters in depth.

The anode shall be a disc or plate of pure silver some 30 square centimeters in area and 2 or 3 millimeters in thickness.

This shall be supported horizontally in the liquid near the top of the solution by a silver rod riveted through its center. To prevent the disintegrated silver which is formed on the anode from falling upon the kathode, the anode shall be wrapped around with pure filter paper, secured at the back by suitable folding.

The liquid shall consist of a neutral solution of pure silver nitrate, containing about 15 parts by weight of the nitrate to 85 parts of water.

The resistance of the voltameter changes somewhat as the current passes. To prevent these changes having too great an effect on the current, some resistance besides that of the voltameter should be inserted in the circuit. The total metallic resistance of the circuit should not be less than 10 ohms.

Method of Making a Measurement.—The platinum bowl is to be washed consecutively with nitric acid, distilled water and absolute alcohol; it is then to be dried at 160° C., and left to cool in a desiccator. When thoroughly cool it is to be weighed carefully.

It is to be nearly filled with the solution and connected to the rest of the circuit by being placed on a clean insulated copper support to which a binding screw is attached.

The anode is then to be immersed in the solution so as to be well covered by it and supported in that position; the connections to the rest of the circuit are then to be made.

Contact is to be made at the key, noting the time. The current is to be allowed to pass for not less than half an hour, and the time of breaking contact observed.

The solution is now to be removed from the bowl and the deposit washed with distilled water and left to soak for at least six hours. It is then to be rinsed successively with distilled water and absolute alcohol and dried in a hot-air bath at a temperature of about 160° C. After cooling in a dessicator it is to be weighed again. The gain in mass gives the silver deposited.

To find the time average of the current in amperes, this mass, expressed in grams, must be divided by the number of seconds during which the current has passed and by 0.001118.

In determining the constant of an instrument by this method, the current should be kept as nearly uniform as possible and the readings of the instrument observed at frequent intervals of time. These observations give a curve from which the reading corresponding to the mean current (time-average of the current) can be found. The current, as calculated from the voltameter results, corresponds to this reading.

The current used in this experiment must be obtained from

a battery and not from a dynamo, especially when the instrument to be calibrated is an electrodynamometer.

SPECIFICATION B.—*The Volt.*

Definition and Properties of the Cell.—The cell has for its positive electrode, mercury, and for its negative electrode, amalgamated zinc; the electrolyte consists of a saturated solution of zinc sulphate and mercurous sulphate. The electromotive force is 1.434 volts at 15° C., and between 10° C. and 25° C., by the increase of 1° C. in temperature, the electromotive force decreases by .00115 of a volt.

1. *Preparation of the Mercury.*—To secure purity it should be first treated with acid in the usual manner and subsequently distilled *in vacuo.*

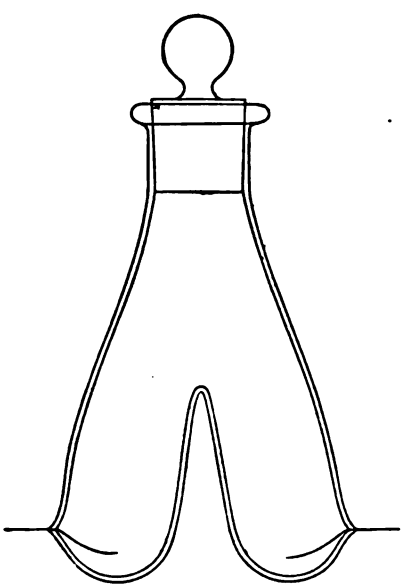
2. *Preparation of the Zinc Amalgam.*—The zinc designated in commerce as "commercially pure" can be used without further preparation. For the preparation of the amalgam one part by weight of zinc is to be added to nine (9) parts by weight of mercury and both are to be heated in a porcelain dish at 100° C. with moderate stirring until the zinc has been fully dissolved in the mercury.

3. *Preparation of Mercurous Sulphate.*—Take mercurous sulphate, purchased as pure, mix with it a small quantity of pure mercury and wash the whole thoroughly with cold distilled water by agitation in a bottle; drain off the water and repeat the process at least twice. After the last washing, drain off as much of the water as possible. (For further details of purification, see Note A.)

4. *Preparation of the Zinc Sulphate Solution.*—Prepare a neutral saturated solution of pure re-crystallized zinc sulphate, free from iron, by mixing distilled water with nearly twice its weight of crystals of pure zinc sulphate and adding zinc oxide in the proportion of about 2 per cent. by weight of the zinc sulphate crystals to neutralize any free acid. The crystals should be dissolved with the aid of gentle heat, but the temperature to which the solution is raised must not exceed 30° C. Mercurous sulphate, treated as described in 3, shall be added in the proportion of about 12 per cent. by weight of the zinc sulphate crystals to neutralize the free zinc oxide remaining, and then the solution

filtered, while still warm, into a stock bottle. Crystals should form as it cools.

5. *Preparation of the Mercurous Sulphate and Zinc Sulphate Paste.*—For making the paste, two or three parts by weight of mercurous sulphate are to be added to one by weight of mercury. If the sulphate be dry, it is to be mixed with a paste consisting of zinc sulphate crystals and a concentrated zinc sulphate solution, so that the whole constitutes a stiff mass, which is permeated throughout by zinc sulphate crystals and globules of mercury. If the sulphate, however, be moist, only zinc sulphate crystals are to be added ; care must, however, be taken that these occur in excess and are not dissolved after continued standing. The mercury must, in this case also, permeate the paste in little globules. It is advantageous to crush the zinc sulphate crystals before using, since the paste can then be better manipulated.



To Set up the Cell.—The containing glass vessel, represented in the accompanying figure, shall consist of two limbs closed at the bottom and joined above to a common neck fitted with a ground

glass stopper. The diameter of the limbs should be at least 2 cms. and their length at least 3 cms. The neck should be not less than 1.5 cms. in diameter. At the bottom of each limb a platinum wire of about 0.4 mm. diameter is sealed through the glass.

To set up the cell, place in one limb pure mercury and in the other hot liquid amalgam, containing 90 parts mercury and 10 parts zinc. The platinum wires at the bottom must be completely covered by the mercury and the amalgam respectively. On the mercury, place a layer one cm. thick of the zinc and mercurous sulphate paste described in 5. Both this paste and the zinc amalgam must then be covered with a layer of the neutral zinc sulphate crystals one cm. thick. The whole vessel must then be filled with the saturated zinc sulphate solution, and the stopper inserted so that it shall just touch it, leaving, however, a small bubble to guard against breakage when the temperature rises.

Before finally inserting the glass stopper, it is to be brushed round its upper edge with a strong alcoholic solution of shellac and pressed firmly in place. (For details of filling the cell, see Note B.)

NOTES TO THE SPECIFICATIONS.

(A.) *The Mercurous Sulphate.*—The treatment of the mercurous sulphate has for its object the removal of any mercuric sulphate, which is often present as an impurity.

Mercuric sulphate decomposes in the presence of water into an acid and a basic sulphate. The latter is a yellow substance—turpeth mineral—practically insoluble in water; its presence, at any rate in moderate quantities, has no effect on the cell. If, however, it be formed, the acid sulphate is also formed. This is soluble in water and the acid produced affects the electromotive force. The object of the washings is to dissolve and remove this acid sulphate, and for this purpose the three washings described in the specification will suffice in nearly all cases. If, however, much of the turpeth mineral be formed, it shows that there is a great deal of the acid sulphate present, and it will then be wiser to obtain a fresh sample of mercurous sulphate, rather than to try by repeated washings to get rid of all the acid.

The free mercury helps in the process of removing the acid, for the acid mercuric sulphate attacks it, forming mercurous sulphate.

Pure mercurous sulphate, when quite free from acid, shows on repeated washing a faint yellow tinge, which is due to the formation of a basic mercurous salt distinct from the turpeth mineral, or basic mercuric sulphate. The appearance of this primrose yellow tint may be taken as an indication that all the acid has been removed; the washing may with advantage be continued until this tint appears.

(B.) *Filling the Cell.*—After thoroughly cleaning and drying the glass vessel, place it in a hot-water bath. Then pass through the neck of the vessel a thin glass tube reaching to the bottom to serve for the introduction of the amalgam. This tube should be as large as the glass vessel will admit. It serves to protect the upper part of the cell from being soiled with the amalgam. To fill in the amalgam, a clean dropping tube about 10 cms. long, drawn out to a fine point, should be used. Its lower end is brought under the surface of the amalgam heated in a porcelain dish, and some of the amalgam is drawn into the tube by means of the rubber bulb. The point is then quickly cleaned of dross with filter paper and is passed through the wider tube to the bottom and emptied by pressing the bulb. The point of the tube must be so fine that the amalgam will come out only on squeezing the bulb. This process is repeated until the limb contains the desired quantity of the amalgam. The vessel is then removed from the water bath. After cooling, the amalgam must adhere to the glass and must show a clean surface with a metallic lustre.

For insertion of the mercury, a dropping tube with a long stem will be found convenient. The paste may be poured in through a wide tube reaching nearly down to the mercury and having a funnel-shaped top. If the paste does not move down freely it may be pushed down with a small glass rod. The paste and the amalgam are then both covered with the zinc sulphate crystals before the concentrated zinc sulphate solution is poured in. This should be added through a small funnel, so as to leave the neck of the vessel clean and dry.

For convenience and security in handling, the cell may be mounted in a suitable case, so as to be at all times open to inspection.

In using the cell, sudden variations of temperature, should, as far as possible, be avoided, since the changes in electromotive force lag behind those of temperature.

EXTRACTS FROM THE ENGINEERING PRESS.

MASTER MECHANICS' ASSOCIATION SCHOLARSHIPS.—The following circular has been issued to members of the Master Mechanics' Association :

The members of the American Railway Master Mechanics' Association are not enjoying the full benefits of the scholarships purchased in the Stevens Institute of Technology. The association expended a large sum of money on these scholarships, and it was confidently expected that there would be warm rivalry among those entitled to compete for entry to the institution; but up to the present time there has not been the full complement of students. At present there are only three students, and one of them will graduate this summer, leaving two vacancies to be filled. There is an excellent preparatory school in connection with the Stevens Institute, which the trustees have thrown open to those entitled to the benefits of our scholarships. If a candidate for the institute does not think himself competent to pass the entering examination of the institute he may take a year at the preparatory school, if the full complement of scholars is not already in the institute.

Sons of all members of the association in good standing are entitled to compete for an entry to enjoy the benefits of the scholarships in the Stevens Institute of Technology. But it is necessary that the candidate should have spent at least one year working in a machine shop.

The next examination for candidates will be held at the Stevens Institute of Technology, Hoboken, N. J., June 7 to 13. There will be another examination from Sept. 16 to 20.

The engineering education imparted to students of Stevens Institute is of such a high character that graduates are eagerly sought after by engineering and manufacturing establishments. The education assures a student the best prospects for rapid advancement in the engineering profession. A father cannot provide his son with better prospects for success in life than by giving him the means of obtaining the education imparted by the four years' course in the Stevens Institute of Technology.

Members who wish to enter their sons for the institute can obtain full particulars by applying to Angus Sinclair, secretary, 256 Broadway, New York.

WILLIAM GARSTANG, President.

The above circular affords a curious commentary upon one of the peculiarities of human nature. This association, at considerable trouble and expense to itself, has succeeded in securing for the sons of its members four scholarships at the Stevens Institute of Technology. No engineering or technical school of any description ranks higher. As stated in the circular, "its graduates are eagerly sought after by engineering and manufacturing establishments. The education assures a student the best prospects for rapid advancement in the engineering profession." The four years' course covers all that appertains to the profession of mechanical engineer. The faculty embraces names known in every field of technical science, and the practical nature of the instruction is evidenced by the variety of the machinery in its workshops and the apparatus in its laboratories. And yet it is stated that up to the present time but three of the scholarships have been filled, and one of these will be vacated by graduation next summer.

In the classical schools, or those devoted exclusively to the inculcation of the so-called "liberal arts," the idea of a scholarship going begging for lack of a claimant was never heard of. The usual ratio is several applicants to one scholarship, and this, too, in view of the fact that such favors are often hedged around with sacrificial conditions. In the present instance there are no conditions beyond the mere fact of eligibility.

The peculiarity referred to is that which has always made a self-made man averse to gratuitous assistance. Many of the members of the Master Mechanics' association are emphatically self-made men. They have worked themselves up from the footboard and the bench, and have received many hard knocks in the course of the ascent. They are conscious that in most cases the knocks have had a subsequent compensation. The only question necessary to ask is whether, under the change conditions which thirty years have produced, they are willing that their sons should undergo the same kind of experience.

The amount and kind of preparation which thirty years ago fitted a man for the best positions in the mechanical line are wholly inadequate now. At best the uneducated young mechanic can hope to take only a mediocre position, and after years of practical experience be content to see the higher places filled over his head by the newly fledged graduates of the technical schools. If, therefore, the members of the Master Mechanics' association who have sons eligible to these scholarships are holding back from assuming their rights on the ground that it is better for the son to follow in the footsteps of his father, they are making a grave mistake. It may be that this is not the case. It may be that the opportunity is so new that its advantages have not yet been fully presented. In any case, it

is hoped that the "warm rivalry" desired by the association may soon show signs of development.—*The Railway Age.*

ELECTRICITY FOR MINING PLANTS — CONCLUDED.* —The "constant expenses" include the salaries of attendants, linemen, dynamo-tenders, etc., that are approximately constant within a wide range of horse-power delivered. Although the fixed charges for the proposed electrical plant are for quite different service than the annual expense for engineers, firemen and machinists, an approximate estimate will show that they are about the same for each plant, and, therefore, may be omitted from each side of the following equation:

$$P_s \times F_s + A \times S \times N = P_e F_e + P_h F_h + P_l F_l.$$

Now, let P_s = 6 per cent. interest + 4 per cent. repairs + 4 per cent. for sinking fund for renewal of boilers, etc., = 14 per cent.

Take cost of steam plant, $75 per horse-power, $37,500.

Taking $4 per cord for wood as equal to coal at $10 per ton, the boiler evaporation at 8 pounds and engine duty 25 pounds of water per horse-power per hour, we find the cost of horse-power per year, with other expenses, as already calculated.

Let $F_e = 500 \times 200 = \$100{,}000$, an extreme figure, assuming special sectional machinery is required.

Let P_e = 6 per cent. interest + 4 per cent. depreciation + 4 per cent repairs = 14 per cent.

$F_h = 500 \times 75 = \$37{,}500$ = cost of hydraulic plant.

P_h = 6 per cent. interest + 4 per cent. repairs = 10 per cent.

P_l = 6 per cent. + 2 per cent. repairs = 8 per cent.

We have now to find the value of F_l to ascertain how much may be spent for conductors and still keep the final total cost per year per horse-power at the present rate.

Substituting and reducing:

$$500 \times 75 \times .14 + 500 \times 75 = 100{,}000 \times 14 + 37{,}500 \times .10 + .08\ F_l$$

$$\$25{,}000 = .08\ F_l.$$

$$F_l = \$312{,}500.$$

It is now a simple matter to find what distance the line can be run for the amount given, after fixing upon the electro-motive force to be allowed between the terminals and the per cent. loss on the line.

(See paper by Edward D. Self, in Quarterly for July, 1894.)

For this problem take 16 cents per pound as the cost of the copper. Here, as in the article cited, it would be manifestly unwise, for financial reasons, to expend $312,500 for copper,

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* This, the conclusion of the extract published in the January INDICATOR, was there omitted through an unfortunate mistake.—ED.

the amount theoretically allowable. There is, therefore, a wide margin for acquiring and improving water rights. Suppose we conclude to spend $50,000 for a pole line and operate the line at 20 per cent. drop, we shall then find it will pay to secure and improve by storage reservoirs or otherwise any waterfall within a radius of nearly 14 miles, if 2,000 volts E. M. F. be employed, or 21 miles at 3,000 volts pressure. The annual interest charge, if the entire sum be expended, would allow the same profit on the product of the mine as if fuel were being purchased at $4 per cord. By assuming the amount to be expended for pole line, etc., and substituting in the above equation, we can determine the value of the electric plant in the price of wood per cord or coal per ton. The difference between the actual cost of fuel and the so calculated cost may be taken as a convenient measure of the advantages of electricity over steam.

No further comment is required to emphasize the peculiar adaptability of electric transmission of power to aid in the solution of one of the most difficult of mining and milling problems —the disappearance of fuel.—*Edw. D. Self*, '86, *in The School of Mines Quarterly, November*, 1894.

THE MIDWINTER MEETING OF THE ALUMNI ASSOCIATION.

The regular Midwinter Meeting of the Alumni Association of Stevens Institute was called to order by President Hewitt, in the High School Lecture Hall, Wednesday, Feb. 20th, 1895.

The President, after his speech of welcome, announced that, as the object of the Midwinter Meeting was the promotion of social intercourse, the regular order of business would not be adhered to.

On motion, duly made and carried, the reading of the minutes was dispensed with, and the minutes of the previous meeting were approved as printed in the INDICATOR.

The Mandolin, Glee and Banjo Clubs of the undergraduates were present by invitation, and added greatly to the enjoyment of the meeting by rendering excellent musical selections in a highly creditable manner during the evening.

After the Mandolin Club had opened the musical part of the program with selections which were much appreciated, the President stated that it was with a great deal of pleasure he exercised his privilege to call for remarks from one so greatly respected among us as President Morton.

President Morton took for his subjects the Alumni Building Fund and the Financial Condition of the Institute. Both the Fund and the Institute were in good shape, the President stated, notwithstanding the hard times. The slow rate of increase of the Fund he considered entirely due to the times, but noted that there is a steady growth of $1,500 a year from interest alone.*

He expressed his judgment that when the Fund suffices to pay for a definite and useful portion of the proposed building the erection of that portion should be at once begun.

After the Glee and Banjo Clubs had each rendered selections Prof. Krœh on being called upon made a very interesting address, giving the result of the vote of the Alumni as to the languages which should be required for admission and taught in his department The general expression of the vote was that Spanish be omitted and French and German taught.

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* This includes the interest on the $20,000 of bonds, whose income for a term of years President Morton has contributed to the Fund, and the interest on about $11,000 of the Fund subscribed, collected to date and invested.

The decision of the Faculty in the matter, Prof. Krœh stated, was to appear in the new catalogue of the Institute, and was to the effect that the course in German would be required to be taken as heretofore. The course in French would be required to be taken by those not desiring to take Spanish, and those students desiring to take Spanish would be required to pass an entrance examination in French.

Following Prof. Krœh, Mr. Craft, '95, sang a soprano solo, and then gave an amusing imitation of Prest. Morton's phonograph.

Prof. Leeds was next called upon and was listened to with much interest.

The Mandolin Club gave several selections, and Messrs. H. C. and R. L. Messimer, accompanied by the Glee Club, sang "Susan Brown."

Those present will not soon forget the happy vein in which Prof. Denton responded when called upon. His criticism of an imaginary letter from the Executive Committee notifying the Professors "that they might say a few words at the meeting" started the laughter, and the submission of a "senior compound conundrum" and other "serious ideas," kept it going until he closed by reading, "as a topic to provoke discussion," an appropriate poem entitled "Sand."

All present joined in singing "The Mechanical Engineer," and the meeting adjourned.

An excellent collation was then served, old friendships renewed, and new acquaintanceships formed, and many an expression of satisfaction uttered over the increasing interest and enjoyment found in the Midwinter Meetings.

LIST OF MEMBERS IN ATTENDANCE.

President, Henry Morton,		H. E. Griswold,	'88
Prof. C. W. MacCord,		A. S. Miller,	"
" A. R. Leeds,		J. V. L. Pierson,	"
" C. F. Krœh,		A. L. Shreve,	"
" J. E. Denton,	'75	J. Eastwood,	'89
Asst. Prof. A. Riesenberger,	'76	H. L. Ebsen,	"
" " W. H. Bristol,	'84	D. H. Gildersleeve,	"
" " D. S. Jacobus,	'84	R. C. Oliphant,	"
" " R. M. Anderson,	'87	J. S. De Hart,	'90
" " S. D. Graydon,	'75	A. H. Hall,	"
" " G. L. Manning,	'91	E. H. Peabody,	"
William Hewitt,	'74	G. L. Todd,	"
J. M. Cremer,	'76	J. A. Davis,	91
P. E. Raqué,	"	A. J. Dixon,	"
A. R Wolff,	"	E. Lorsch,	"
F. E. Idell,	77	L. H. Nettleton,	"

L. H. Nash,	'77	A. R. Hake,	'92
A. A. de Bonneville,	'78	F. E. Law,	"
F. C. Jones,	"	H. Loenherz,	"
E. P. Thompson,	"	W. O. Ludlow,	"
W. W. Dashiell,	'79	H. C. Meyer, Jr.,	"
J. W. Lieb, Jr.,	'80	A. J. Post, Jr.,	"
J. Wetzler,	'82	H. D. Reed,	"
W. L. Lyall,	'84	Chas. F. Vogelius,	"
H. de B. Parsons,	"	L. Waefelaer, Jr.,	"
E. Burhorn,	'85	O. C. Whitney,	"
B. H. Coffey,	"	H. A. Adams,	'93
W. N. Stevens,	'85	A. E. Bruen,	"
W. C. Post,	'86	O. G. Dale,	"
J. H. Cuntz,	'87	F. D. Furman,	"
J. D. Flack,	"	E. D. Lewis,	"
J. R. Onderdonk,	"	A. B. Lord,	
C. H. Page, Jr.,	"	F. L. Parker,	"
H. A. Bang,	'88	J. V. Macdonald,	"
R. Beyer,	"	Chas. F. Rittenhouse,	"
G. Campbell,	"	W. H. H. Roberts, Jr.,	"
N. St. G. Campbell,	"	J. Cottier,	'94
G. Dinkle,	"	D. Corbin,	"
P. A. Doty,	"	C. C. Hartpence,	"

The following members of Stevens Glee, Banjo and Mandolin Clubs contributed to the enjoyment of the evening.

D. D. Barnum,	'95	O. A. Pope,	'96
S. Cooper,	"	P. D. Wagoner,	"
M. E. Craft,	"	A. C. Woodward,	"
R. E. Hall,	"	C. Hidden,	"
E. M. Harrison, Jr.,	"	J. F. Hunter,	'97
F. N. Mac Veety,	"	G. L. Hutchins,	"
F. N. Taff,	"	W. A. Kirkland,	"
E. A. Greenidge,	"	H. C. Mathey,	"
J. P. Badenhausen,	'96	R. L. Messimer,	"
L. J. Borland,	"	G. P. Richardson,	"
R. E. Bruckner,	"	M. Ruggles,	"
E. Campbell,	"	A. De L. Smith,	"
J. P. Evertz,	"	G. D. Williamson,	"
A. W. Gunnison,	"	E. N. Wood,	"
H. M. Hardie,	"	R. C. Post,	'98
G. Kollstede,	"	R. S. Scott, Jr.	"
W. H. Mac Gregor,	"	A. Macdonald,	s.s.
H. C. Messimer,	"		

ATHLETIC NOTES.

At the annual convention of the United States Intercollegiate Lacrosse Association, held Feb'y 16th at Philadelphia, the hand-book, "How to Play Lacrosse," edited by W. H. Corbett, '95, and published by the *American Sports Publishing Co.*, was adopted as the official guide of the Association.

The following schedule of games was agreed upon, viz.:

May 11, J. H. U. *vs.* Stevens, at Baltimore.
May 18, Lehigh *vs.* J. H. U.; at Bethlehem.
May 25, Lehigh *vs.* Stevens, at Hoboken.

The formal award to Stevens of the championship for 1894 was made, and the following officers elected:

President—W. H. Corbett, Stevens.
Vice-President—J. C. Dick, Lehigh.
Secretary and Treasurer -J. H. Pleasants, Jr., J. H. U.
Ex. Com.— B. M. Mc Donald, Lehigh,
T. F. P. Cameron, J. H. U.,
J. F. Hunter, Stevens.

An indoor game of Lacrosse was played with the Orange Athletic Club at Orange, N. J., on Feb'y 28th, resulting in a score of 10 to 7 in favor of Stevens.

INSTITUTE NOTES.

THE FOLLOWING PRICES will be paid for the back numbers of the INDICATOR stated below, if delivered in good order to the editors :

$1.00 for each of ten copies of Vol. 7, No. 3 (July, 1890), and for each of ten copies of Vol. 8, No. 4 (Oct., 1891).

50 cents for each of the following :

One copy	Vol. 2,	No.	2.
One "	"	"	4.
Four copies "		"	7.
One copy "		"	8.
Two copies "		"	9.
Two "	Vol. 3,	"	1.
Two "	"	"	5.

PROF. JACOBUS has in progress a test upon the distribution of moisture in steam when flowing through a horizontal pipe. This is a continuation of his Test of Small Throttling Calorimeters, the results of which were presented at the December meeting of the American Society of Mechanical Engineers, and are placed before our readers in this number. The results of the supplementary test will be presented at the Detroit Meeting of the Association this summer.

THE CLASS OF '95 has presented to the Institute for the use of the Department of Electricity a 40-horse-power, high-speed Payne engine, which will be immediately set up and brought into service in connection with work on the graduation theses of several members of the class.

THE BALL AND WOOD ENGINE at the Edison Electric Company's plant in Paterson, N. J., has recently been made the subject of a thorough test by Prof. Jacobus. It is the same compound engine of novel design which was exhibited at the Ball & Wood shops last fall to a delegation of mechanical engineers, and the test was undertaken to determine its steam consumption per horse-power per hour.

PROFESSOR DENTON has taken the senior class to Pittsburg on its Inspection Tour, of which the following was the itinerary :

Monday, March 11th, Philadelphia, Pa. Baldwin Locomotive Works, Cramp Ship Yards, Artificial Ice Plant, Plate System.

Tuesday, March 12th, Drifton, Pa. Coal Mines of Coxe Brothers.

Wednesday, March 13, Altoona, Pa. Locomotive Shops and Laboratories of Pennsylvania R. R.

Thursday, March 14th, Pittsburg, Pa. Carnegie Steel Works and New Offices—the latter remarkable for completeness of heating, cooling and ventilating appliances.

Friday, March 15, Pittsburg, Pa. Westinghouse Electric Company's Shops, Westinghouse Air Brake Company's Shops.

Saturday, March 16th, Pittsburg, Pa. National Tube Works, Pittsburg Water Works.

THE ENGINEERING SOCIETY.

An interesting meeting was held on the 20th of February.

Mr. Robinson, in reviewing the mechanical journals, called attention to "Oil and Fuel" especially for locomotive and steamship service, also to the report of the Army Engineers on the proposed Hudson River Bridge, and to a method of making absolutely tight pipe-joints. Facts were also presented concerning the preservation of iron from rust, and some account of the discovery and properties of Argon.

Mr. Walker described recent progress in electrical matters, such as electrical welding of rails and the B. & O. electric locomotives, and called attention to the publication in English technical and scientific journals of information relative to American achievements of which little is heard in America.

An entertaining feature of the meeting was furnished by Mr. Jackson, who exhibited a number of fine lantern views of South American scenes, covering Valparaiso, Rio de Janeiro, and points on both the west and east coasts.

On March 14th, one of the best attended meetings of the Association was held.

The production, properties and utilization of aluminium was the subject of a paper by Mr. Boucher, which led to an interesting discussion.

Mr. McGregor reviewed the electrical journals, touching on the utility of calcium carbide, the permanency of electrocution, and submitted for discussion a comparison of electric, oil and gas light for lighthouses.

Mr. Wood brought forward the problem of air navigation, giving details of the Maxim flying machine, illustrated by lantern views.

Mr. Kingsford explained with the aid of a drawing the stresses in a bicycle frame with the rider's weight applied at different points.

A special meeting of the Association was held on March 6th, at which a proposition for the publication of the proceedings of the Association in book form was considered and accepted.

It was resolved that a committee of three including the President be appointed to review the matter for publication.

MUSICAL CLUBS.

The season has been an unusually active one, concerts having been given at Hoboken, January 15, Jersey City, January 22, Bergen Point, January 29, Montclair, February 4, Brooklyn, February 12, and Orange, February 14.

The last of the series was an occasion of especially enjoyable character to the members of the clubs, largely due to the kind interest of Mrs. Chas. F. Krœh and the other patronesses, among whom were Mrs. Geo. L. Manning, Mrs. George Campbell, Mrs. E. D. Ruggles, Mrs. C. B. Yardly, Mrs. James M. Ludlow and Mrs. Everett Frazar.

INSTITUTE PERSONALS.

It is our edeavor to notice under this heading such items of news affecting graduates of the Institute as may interest their classmates and friends among the Alumni. We are indebted to a few members for regular or frequent contributions of items, and wish to make it known that the co-operation of all is most desirable, and will be appreciated. MANAGING EDITOR.

'76.

G. C. HENNING delivered a lecture on Feb. 18th at Worcester Polytechnic Institute on Testing Machinery and Apparatus.

WM. KENT delivered an illustrated lecture on Feb. 16 before the Brooklyn Institute of Arts and Sciences, on the Manufacture of Iron and Steel.

'77.

ALEX. G. BRINKERHOFF, Superintendent for Johnson & Morris, Steam Heating and Ventilating, 114 Leonard street, New York, was omitted by mistake of the printers from the list of members of the Alumni Association in the January INDICATOR.

'81.

ALEX. C. HUMPHREYS, who returned from Europe on April 19th, visited the Institute a few days later, bringing his son with him, to learn what preparatory work the entrance requirements for the class of '99 would necessitate. Mr. Humphreys will doubtless be the first Alumnus of Stevens to have a son enter its classes.

Mr. Humphreys reports the completion by his firm of gas plants for Copenhagen, Brussels, Glasgow, Belfast, Liverpool, and Tottenham, London; and the securing of contracts for plants for Southport, Belfast (2d), with capacity of 3,500,000 cu. ft. per day, Brighton, 1,500,000 cu. ft., Preston 1,500,000 cu. ft., and Swansea 750,000.

H. C. WHITE has accepted a position with the Quintard Iron Works, New York City.

'82.

GEO. GIBBS presented the paper of the day, entitled Notes on Modern Practice in Signalling, at the meeting of the Western Railway Club held in Chicago, Feb. 19th. It was published in the *Official Proceedings* of the Club.

'84.

W. F. ALDRICH presented a written discussion of the advantages and disadvantages of gas engines at the meeting of the American Society of Mechanical Engineers held on April 10th, and suggested the establishment of a plant for testing gas engines, similar to the turbine-testing plant at Holyoke.

W. O. BARNES is with the Bleckensderfer M'f'g Co., Stamford, Conn.

S. P. BUSH presented the paper of the day at the meeting of the Western Railway Club on Jan'y 15. His subject was "Methods of obtaining Economy in the Use of Fuel on Locomotives." The paper appears, with the discussion of it, in *Official Proceedings* of the Club for January.

'85.

ANSON W. BURCHARD took part in the discussion held at the meeting of the American Society of Mechanical Engineers on Wednesday, April 10th, on the subject of gas engines, and submitted the results of tests and records covering a period of six months with the Danbury and Bethel Electric Light Company's plant, which is operated by three 100 horse-power Otto gas engines supplied with producer gas.

WILLIAM T. CLERK, who has established himself as an architect in Santa Barbara, California, where Spanish architecture is in favor, has come to New York and will proceed to Spain to study the architecture of that country. His address for the current year is 32 W. 17th street, New York City.

JOHN M. RUSBY was granted, on Jan'y 15th, letters-patent for an improved water gas apparatus, and has assigned his rights under it to the United Gas Improvement Company.

THOS. G. SMITH, JR., contributed to *Cassier's* for February a paper noticing "Recent American Direct Connected Engines and Dynamos."

'86.

E. P. MOWTON has removed to No. 2 Wall street, New York City.

E. F. WHITE may be addressed at 125 E. 1st street, Bayonne, N. J.

'87.

J. H. CUNTZ, in a highly interesting article in *Cassier's* for February, tells clearly how incandescent lamps are made.

'88.

E. J. WILLIS has written for the Feb'y issue of *Cassier's Magazine* a paper on "Combined Efficiencies of Mechanical and Electrical Machines."

'91.

HENRY E. WOLCOTT and SUSAN LAWRENCE, daughter of Richard B. Lawrence of Orange, N. J., were married Feb'y 22, at the Unitarian Church, Orange, N. J.

'92.

HOWARD T. GURNEY and Miss CLARA DEAR of Jersey City, N. J., were married on April 17th.

N. S. HILL, JR., and Miss ISABELLE BURNES BERRY were married at the home of the mother of the bride, Mrs. John T. Berry, 911 St. Paul street, Baltimore, Md., on April 17th.

HERMAN LOWENHERZ, JR., briefly discusses the "Inspection of Steel Rails for Electric Railways" in an article published in *The Electrical Engineer* of Feb'y 6th.

JOHN T. SCHRAMME is a member of the firm of Schramme Bros., formerly Schramme & Fuller, stock brokers, 57 Broadway, N. Y.

'93.

ANSON G. WILBOR has been appointed Assistant Professor of Mathematics and Physics in the Albany Academy, Albany, N. Y.

THEO. LEONHARD, has secured employment as draughtsman with the National Sugar Refining Co., Yonkers, N. Y.

'94.

E. P. BUFFET'S thesis on the Magnetic Properties of Nickel Steel was published by the *American Manufacturer and Iron World*, Pittsburg, Pa., Feb'y 22.

M. W. KELLOGG is with Messrs. Cornell, Hiscock & Underhill, Railroad, Mill, Mine and Furnace Contractors and Supplies, 13 Gold street, New York.

C. W. MACCORD, JR., is now occupying the position of associate editor on *Power*, World Building, N. Y.

JOHN V. L. PIERSON is draughting for Kimball & Thompson, architects, New York City.

INDEX TO CURRENT ENGINEERING LITERATURE.

The following is an Index of the more important articles appearing in the current engineering papers and magazines, and is compiled with the object of aiding our readers to know where to find the most recent information pertaining to the subjects interesting them in the various departments of engineering.

LIST OF PERIODICALS INDEXED.

A list of the papers and magazines indexed is here given, in alphabetical order, together with the office of publication, from which any paper may be obtained, at the price stated below.

Am. Eng.—American Engineer and Railroad Journal. Monthly. 47 Cedar Street, N. Y. Single copy, 25 cents.

A. G. L. J.—The American Gas Light Journal. Weekly. 32 Pine Street, N. Y. Single copy, 10 cents.

A. J. S.—The American Journal of Science. Monthly. New Haven, Conn. Single copy, 50 cents.

Am. Mach.—American Machinist. Weekly. 96 Fulton Street, N. Y. Single copy, 10 cents.

Cassier's.—Cassier's Magazine. Monthly. World Building, N. Y. Single copy, 25 cents.

El. Eng.—The Electrical Engineer. Weekly. 203 Broadway, N. Y. Single copy, 10 cents.

El. W'ld.—The Electrical World. Weekly. 177 Times Building, N. Y. Single copy, 10 cents.

Elec'n.—The Electrician. Weekly. 1, 2 and 3 Salisbury Court, Fleet Street, London, E. C. Single copy, 4½d.

Elec'y.—Electricity. Weekly. 6 Park Place, N. Y. Single copy, 10 cents.

Eng'r. (Am.)—The Engineer (American). Weekly. 106 and 108 Fulton Street, N. Y. Single copy, 10 cents.

Eng'r. (Lon.)—The Engineer (London). 33 Norfolk Street, Strand, W. C., London. New York Agency, International News Co., 83 Nassau Street, N. Y. City. Single copy, 6d.

Eng'g.—Engineering. Weekly. 35 and 36 Bedford Street, Strand, London, W. C. Single copy, 6½d. Agency, Mr. W. H. Wiley, 53 East Tenth Street, N. Y.

Eng. Mag.—The Engineering Magazine. Monthly. 47 Times Building, N. Y. Single copy, 25 cents.

Eng. Mech.—Engineering Mechanics. Monthly. 430 Walnut Street, Philadelphia, Pa. Single copy, 10 cents.

E. & M. J.—Engineering and Mining Journal. Weekly. 27 Park Place, N. Y. Single copy, 15 cents.

Eng. News.—Engineering News and American Railway Journal. Weekly. Tribune Building, N. Y. Single copy, 15 cents.

Eng. Rec.—Engineering Record. Weekly. 277 Pearl Street, N. Y. Single copy, 12 cents.

H. & V.—Heating and Ventilation. Monthly. World Building, N. Y. Single copy, 10 cents.

I. & R.—Ice and Refrigeration. Monthly. 206 Broadway, N. Y. Single copy, 25 cents.

Ind.—Industry. Monthly. 40 California Street, San Francisco, Cal. Single copy, 20 cents.

Ir. Age. Iron Age. Weekly. 100 Reade Street, N. Y. Single copy, 10 cents.

J. A. E. S.—Journal of the Association of Engineering Societies. Monthly. 419 Locust Street, Philadelphia, Pa. Single copy, 30 cents.

J. C. S.—Journal of the Chemical Society. Monthly. 1 Paternoster Row, London, Eng.

J. F. I.—The Journal of the Franklin Institute. Monthly. Philadelphia. Single copy, 50 cents.

Lo. Eng. Locomotive Engineering. Monthly. 256Broadway, N. Y. Single copy, 20 cents.

Mach. Machinery. Monthly. 411 Pearl Street, N. Y. Single copy, 5 cents.

N. C. & L. B. The National Car and Locomotive Builder. Monthly. 140 Nassau Street, N. Y. Single copy, 20 cents.

Nat.—Nature. Weekly. 29 Bedford Street, Strand, W. C., London, Eng. Single copy, 6d.

Ph. Mag. The London, Edinburgh and Dublin Philosophical Magazine and Journal of Science. Monthly. Red Lion Court, Fleet Street, London, Eng. Single copy, 5s.

Pow.—Power. Monthly. World Building, N. Y. Single copy, 10 cents.

P. E. C. P.—Proceedings of the Engineers' Club of Philadelphia. Quarterly. 1122 Girard Street, Philadelphia, Pa. Per year, $2.

P. R. S. Proceedings of the Royal Society. Occasional. 37 Soho Square, London, Eng. Price varies.

P. U. S. N. I.—Proceedings of the United States Naval Institute. Quarterly. Annapolis, Md. Single copy, $1.

Pr. Age. Progressive Age. Semi-monthly. 280 Broadway, N. Y. Single copy, 15 cents.

R. R. C. J. The Railroad Car Journal. Monthly. 132 Nassau Street, N. Y. Single copy, 10 cents.

R. R. G. Railroad Gazette. Weekly. 73 Broadway, N. Y. Single copy, 10 cents.

R'y Age. The Railway Age and Northwestern Railroader. Weekly. Monadnock Block, Chicago, Ill. Single copy, 10 cents.

R. E. & M. Railway Engineering and Mechanics. Monthly. The Rookery, Chicago, Ill. Single copy, 10 cents.

S. M. Q. School of Mines Quarterly. Columbia College, N. Y. Single copy, 50 cents.

Sc. Am. Scientific American. Weekly. 361 Broadway, N. Y. Single copy, 10 cents.

S. A. S. Scientific American Supplement. Weekly. 361 Broadway, N. Y. Single copy, 10 cents.

S. J. E. Sibley Journal of Engineering.

St. Ind. Stevens Indicator. Quarterly. Stevens Institute, Hoboken, N. J. Single copy, 50 cents.

S. R. J. Street Railway Journal. Monthly. World Building, N. Y. Single copy, 35 cents.

T. A. I. E. E. Transactions of the American Institute of Electrical Engineers. Monthly. 12 West Thirty-first Street, New York City.

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THE STEVENS INDICATOR.

VOL. XII. JULY, 1895. No. 3

ABSTRACT OF LECTURE DELIVERED BEFORE SENIOR CLASS OF STEVENS INSTITUTE OF TECHNOLOGY.

BY PROF. COLEMAN SELLERS, E.D.

THE lectures delivered by the Professor of Engineering Practice of the Stevens Institute of Technology are expected to bring you, as students, in closer touch with engineering work as it is carried on at the present time, and to show how the knowledge acquired in the regular course of studies can be applied to the best advantage, as well as to encourage you in regard to your work, and to show, if possible, that all of the college work, no matter how seemingly useless at the time, will surely be of use if followed up, appreciated and forced into use by practice.

Those of you who have had shop practice before entering this school, and, feeling the need of technical education, have sought it of your own free will, need no assurance from me as to the ultimate value of all branches of the scientific studies forced on you during your term here. Before the state of the arts called for high technical education, the classics and mathematics were deemed essentials for education to teach modes of thought, and were used as methods of training to strengthen the mind. Few young men nowadays can spare time to follow the old course in Latin and Greek and the living languages, and also to take up the full line of studies required in your case, and which of themselves task your mental efforts to the utmost.

There are students who thirst for knowledge of all kinds. Some, knowing the good that will result from their exertions,

become students by natural bent, taking to work as a pleasing duty, and becoming fond of the very subjects which at first filled them with discouragement and anxiety. Such young men grow up to habits of industry, and find pleasure in working. Such students learn sooner or later that in work only can a healthy man find rest and recuperation. The enthusiastic hunter labors physically harder than many laboring men, and calls it sport. Humboldt, Agassiz, and a host of others, led lives of unremitting labor, both mental and physical, desiring no other condition of life than that of hard work. Such men keep clear of all the deep ruts that cramp and limit the scope of some specialists who follow some one line of thought. The road in which they move is broken down by paths in all directions, and no subject is unworthy of their attention.

Before the foundation of any technical schools, the education supplied by the highest colleges proved to be of very little value to any except those who were aiming to follow the so-called learned professions of divinity, law, medicine, etc. A striking illustration of the insufficiency of the instruction, so far as engineers are concerned, was manifested to me at the time your President, Dr. Morton, was Secretary of the Franklin Institute in Philadelphia, or rather previous to his being appointed, when he was applying himself diligently to acquiring a proficiency in knowledge of physics and chemistry beyond what college education had given him. He graduated from the University of Pennsylvania with honor, having done most excellent work while connected with that institution. The Franklin Institute was founded by some earnest men who felt the need of some better education than could be given to them in the schools, and which would be of use to them in their business as mechanics or manufacturers. The professors of the University of Pennsylvania, at least those who taught chemistry and natural philosophy, and many students of the sciences, found the Franklin Institute a useful school for themselves, because they came in contact there with practical men, and acquired an amount of information which they could not have obtained from any books published at that time. The kindly feeling which existed between the professors of the University of Pennsylvania and the members of the Franklin Institute at the

founding of the latter, has been kept up ever since, and it is worth noting that the present venerable President of the American Philosophical Society is proud to claim the Franklin Institute as the sole and only means of his having acquired the general knowledge that fitted him to be the administrative head of a dignified and learned society.

The Central High School of Philadelphia sprang from the Franklin Institute's attempt to teach technical sciences by lectures and night classes, but the greatest advance in the Franklin Institute came with the active work done by Dr. Morton as Resident Secretary, after the constitution of the Institute was changed from its first design to one permitting the appointment of a Resident Secretary who would be a man of sufficient technical ability to make him of use to the members as an adviser, and who could bring before the society all the most remarkable instances of engineering practice which might be needed by the members, and which might be of use to them in their business. The interest that men like Prof. Bates, Prof. Rogers and Prof. Frazer had taken in the Institute showed the advantage of bringing the practical working men into close connection with those who might be considered as purely theoretical men, to the mutual benefit of both.

Men like Oliver Evans, and others of the early engineers, who undertook to express their ideas in writing, were close observers of physical phenomena without being proficient mathematicians. When Dr. Morton was made Secretary of the Franklin Institute, and later editor of the *Journal*, his work in the Institute seemed to bear immediate fruit, and the lectures which he delivered at the Academy of Music stood at that time as unequalled in brilliancy and utility, so that his connection with the Franklin Institute marked an era of improvement.

When Dr. Morton was made President of the Stevens Institute, he came to Hoboken with a fuller knowledge of the needs of the mechanical engineers than most college-bred men, from his close connection with the practical engineers of Philadelphia, and at the same time, he understood the deficiencies that existed in the course pursued in the colleges generally. Dr. Morton had a clear idea of what would be required in a school of mechanical engineering, and he knew also the limit

of such instruction, and was perfectly well aware that the best education would have to be supplemented by very considerable actual practice. The course pursued in the Stevens Institute, being what was mapped out by its President from the beginning, through the aid of those collected about him, has resulted in turning out a number of men who have acquitted themselves well in active, practical life, and each of these men has, as a graduate, proved the correctness of the methods.

Late in the autumn of last year I had the pleasure of a visit to the McGill University, at Montreal, and had an opportunity to address all the class of the scientific department, to describe to them, as far as I could in a brief way, the work that is being done at Niagara Falls, in the State of New York, to utilize the water-power of that great cataract. In talking to the Dean of the Faculty, I learned from him that he had heard frequent expressions from people who were seeking the services of graduates of scientific schools, to the effect that the students of the Stevens Institute came to their work with less self-conceit and a more earnest desire to acquaint themselves with the practical needs of engineering than those from some other institutions professing to send out full-fledged engineers, who should be capable of following their professions from the beginning, and who would aim to be directors from the commencement, rather than useful assistants.

It is a noteworthy fact that for a great many years manufacturers looked upon college graduates as not of nearly so much use to them as those who had served regular apprenticeships to the trade and had grown up in business from boyhood, even though the technical knowledge of the shop-trained students was very much less than that of the students from the technical schools. It was Dr. Morton's intention from the beginning to have the students impressed with the idea that at the most they could only learn how to study, and must continue the life of a student after they should get into actual work and come in contact with practical men. Since that time a great many industries have been started that could not exist without a higher education than was possible a few years ago, and notable among these are the establishments for manufacturing electrical machinery.

Electrical engineering, considered as distinct from engineering in its broadest meaning, can be studied and discussed with satisfaction only with a knowledge of mathematical methods. Faraday was not a trained mathematician; he could not follow processes by means of symbols; he excelled in experimental demonstration wholly. Great as was his work, how much more could he have done had he possessed the mental training you are supposed to have after your four years at Stevens!

Frequently I am asked the value of a thorough electrical education for would-be electricians, who see in the electricity of the future the greatest power in the world. Such men begin by thinking that when our coal is exhausted we will fall back on electricity to light our houses, cook our dinners, and to operate our shops and railroads. They do not see the steam-engine or the water-wheel that drives the generator; they do not realize that the successful electrician, so far as designing is concerned, must also be the best mechanical engineer. Electricity, as we know it now, is only a mode of transmitting motion, but it is not of itself a prime mover or source of power. A pound of coal burned gives its equivalent of heat or its equivalent of light through its equivalent of electricity. There is, perhaps, no branch of engineering practice that is more easily understood and mastered than the arithmetic of electricity, as it is to be used in the trade; but to study electricity as a science, what is wanted comes to the man who is not a mathematician as something that is too difficult for him to undertake, and when he forces himself to the study of it, he meets with discouragement from his ignorance of mathematics, and partly from the lack of clearness in the writers, and partly from the great volume of immaterial matter that hides the real truths that are needed for a clear understanding of the subject.

Correlation of forces and conservation of energy must be taught with the A, B, C of the common school before the masses will learn to classify and put in its proper place in their minds all that is offered to them and all that comes to them as new and wonderful; but the students of technical schools have advantages beyond others, with their minds trained to discriminate between the true and the false.

In the present course of lectures, as an example in engineering practice, I intend to give you as clear an idea as I can of the work that is being done at Niagara, as, since my lectures of last year and the year before, this work has been pushed to a further stage, and is being developed on lines that were not contemplated then. I shall probably, in the last lecture of my course, venture to call your attention to subjects that are not strictly germane to an engineering course; but, in consultation with President Morton, I am satisfied that it will be to your advantage for me to call your attention to a matter that he himself has seen fit to bring before the class, viz.: mistakes and fallacies in science. This is suggested to me by the paper which has recently appeared in the INDICATOR, being a lecture delivered a number of years ago before the senior class of the Stevens Institute of that year, in which he alluded to perpetual-motion machines and other fallacies. My attention lately has been drawn to some of the most surprising productions of men who are celebrated as physicists, and who may yet have been led astray by endeavoring to apply scientific truths and lawful methods to solve what is doubtless the basest fraud. I have so often been called to advise in such matters, that I feel that it is part of my duty to put you on your guard against mistakes, and to give you some hints as to methods of observation.

The business part of engineering, the cost involved in work, is a matter that should have your most careful attention. You are now about entering upon your life work at a time of great commercial depression. It is during such periods of commercial depression that we find the most difficulty in obtaining the means for necessary engineering improvements, and the cost of all such work is more carefully weighed when times are bad than when we are in the high tide of prosperity, and money is more easily obtained. It is necessary for you, as engineers, therefore, to have as thorough a knowledge as possible of business methods, of the methods of successful merchants, to appreciate the value of money, to carefully weigh your plans in the light of cost. The best engineering is not the accomplishment of an end, whether or no, but the results must be obtained in the best and cheapest manner at the same time, not by bad workmanship or stinting material, but by exercise of judgment

as to the real needs of each case. Your services will be in greater demand if you are capable of exercising good judgment in advising those who employ you, and of being accurate and painstaking in all your work. The mechanical engineer has mainly to deal with matter in motion, as compared to the work done by civil engineers, who may be engaged upon large enterprises, from which they derive great credit and renown. Builders of such structures as the Forth Bridge or the bridge spanning the East River erect monuments to their own fame. The material used in these structures may be placed judiciously; it may be placed so as to be attractive to the eye, and be satisfactory in all respects except in first cost. You have in the bridge-building of America, as compared to that of Europe, methods that are distinctly different and worthy of your most careful consideration, and the same obtains also in regard to structural work. The amount of iron and steel now used in building purposes grows greater every year, and a knowledge of the disposition of these materials, as well as a knowledge of their deficiencies, should be carefully studied by all who expect to make a name for themselves as judicious advisers and skilful engineers.

I may have occasion to refer to the difference in the engineering methods of America and other countries. A few years ago an article appeared in London *Engineering* from the pen of my dear friend, Mr. James Dredge, in which he commented favorably on the value of the papers published in the INDICATOR as proving the value of the method pursued in conducting a journal issued by a school of engineering, in which not only the students took part, but to which the faculty were contributors Mr. Dredge drew attention to some lectures on "engineering practice published in the INDICATOR," and spoke of the great advantage of supplementing technical instruction with the experience of men who have had considerable practice as engineers and who know and value the need of a higher education than that obtainable in the workshops only. One lecture on the design and methods of English workshops, as compared with the American system, Mr. Dredge seemed to consider as perhaps showing an unwillingness to appreciate what English engineers can do and are doing. It has been my intention to

mention this matter to you to keep you from falling into error, and to prevent you from misunderstanding my contrasts of methods, in case I should have occasion to allude to such matters in the present course. I have always endeavored to show that American methods of engineering, as distinct from those of other countries, are the outgrowth of necessity and the result of difference of conditions existing in the different countries. American locomotives differ from the English, and no amount of argument can make the engineers of either country deviate from what may be called their traditional course. We are closer students of what is doing in England, perhaps, than many of the English engineers are of what is being done here; and we owe much of our best work to this study. The changes we are forced to make in introducing European inventions into America are not changes for the mere sake of changes, but for good and sufficient reasons in every case. We are obliged to adapt the design to the constructive ability of our machine tools, to make the design conform to our shop practices, which are not the same, nor are the workmen in both countries alike.

English trades unions, with their stubborn opposition to the efforts of their employers, for instance, forbid a workman to operate more than one machine of a kind; a machinist is forbidden to operate two lathes or two planers. We hold to the advantage of improving our machinery so that when it is possible for more than one machine to be operated by one workman, this end can be attained by making it profitable to the employee to do so by enabling him to earn higher wages in proportion to his ability and his industry.

American labor-saving machines introduced into England have often failed and been discarded as useless, while in this country they have proved for themselves their greater value both to the workmen and to the employer. Englishmen have admitted to me that their study into the reason of this failure to succeed with our tools in England shows it is not the fault of the machines or of the tools, but of the men who are employed to operate them in other countries, who lack the ability to use these improvements to the best advantage; in fact, they say it is lack of education. You will find, however, when you go into American workshops that some of our best labor-savin

machines are operated by foreign-born workmen, a fact that may seem to disprove the assertion that similar machines cannot be used to advantage in England. There are, doubtless, in England particularly, a great many workmen capable of appreciating what they use to advantage when here, but while in their own country they are hampered by trades unions and by their customs. It may also be confidently asserted that those who have succeeded in following the example of the workmen in America, when employed among them, have been of the better class, have had the ambition to leave their fatherland and seek employment in another country. Among the moderately well-to-do middle class of England there are, I think, more amateur mechanics than here, or, perhaps, in a more densely populated country they are nearer to each other and show up more strongly in the publications devoted to their interests. Our libraries are filled with books on machine construction, on specialties relating to machinery and books teaching methods, all coming from the other side of the ocean, which are immeasurably useful to us in many ways. They are often rich in descriptions of ingenious devices. No mechanics' library is complete without the five volumes of Holtzapfel's "Lathe and Mechanical Manipulations." The early volumes, those written by the master, stand alone in abundant utility, but the original writer failed to finish the great work, and his descendants have added later volumes which, in contrast with the great value of the first, second and third, seem of much less account. To be possessed of a Holtzapfel lathe might well be the ambition of a wealthy amateur; but, in the United States, the hardware trade dealers in minor machine tools can fill our wants with a far richer stock from which to make selection of more admirable devices than can be bought in London. I speak from abundant knowledge, as, when in London, I took pains to acquaint myself in this regard. I have only to show you examples, for instance, of steel straight-edges and scales, to show you those graduated in England and those that are in common use in America; but even in the case of the minor hand-tools, which have been brought to such a high state of perfection in America by the interchangeable system of manufacture, we might select, for instance, the ordinary twist drills which, as made by

the Morse Company, came into almost immediate successful use, and which form of drill has been so admirably made in Alsatia. The Atelier de Common produced not only drills of equal quality, but the machine tools employed and perfected by that company for the manufacture of other machinery, surpass in accuracy much that has been made here. As early as 1876 I became possessed of numerous examples of work done in Alsatia by special tools that turn out work surprising as to accuracy of form and exactness of dimension, and showing upon the face undoubted reason to believe that no hand adjustment had been employed to improve the work as it left the machine. In my correspondence with this same house later, I was led to believe that their work had progressed to a still higher state of perfection. I have seen in the English workshops the best examples of not only the best workmanship, but of faultless design.

We are unquestionably indebted to Mr. Whitworth for the first conception of simplicity of form added to perfection of workmanship, and forty years ago no shop was complete without an equipment of standards made by Mr. Whitworth, or at least, copied from him by other English makers. But, in spite of recognition of all that is good, and it is indeed abundant, you will, as you acquire knowedge of conditions, learn to appreciate the superior commercial advantages arising from the American system, not only of machine tools, but of engine construction and everything that goes to make what mechanical engineering is to-day.

When describing to you some of the engineering problems incident to the work at Niagara Falls, I will give you some idea of the difficulties encountered in transmitting large amounts of power by means of bevel gearing. I mention this to urge your attention to the whole subject of transmission of motion by means of toothed wheels, and the importance of the study as to all the known conditions that influence the shape of teeth, the limits of pressure and speed, and the functions of each and every known form of teeth.

In 1857, when I was called to assume the position of chief engineer with the firm of Wm. Sellers & Co., of Philadelphia, makers of machine tools and mill gearing of all kinds, I found

myself compelled to take up the study of this subject and to labor over it diligently for many months. I assumed the task of laying out and filing to shape all the templates required by the pattern-maker, the millwright and the maker of cutters for the gear-cutting machinery. This knowledge could not be obtained wholly from books, and many careful experiments were needed to reach the conditions of knowledge to enable a high step to be taken in designing machinery for forming cutters for gear teeth without the aid of templates. This study was far from complete as prosecuted by myself, and was carried to a higher plane of perfection by others of the staff, through a gradual progress toward perfection.

The invention of the automatic gear-cutting machinery which embodied some of the many modes of motion that we had brought into practice, led later to the attempt to perfect the dividing mechanism by the perfection of the master wheel of each machine. The minute corrections needed for the first dividing wheel extended over more than a year's continuous work for the best class of machinist. In regard to this subject of gear wheels, one cannot wholly rely on the purchase of standard cutters in the open market. The various problems likely to be presented will require the practical engineer to keep in close touch with all his accumulated knowledge, and will require his keeping that knowledge bright and in working order by not neglecting it. Neglect of our mental tools is more hurtful than the neglect of our every-day working implements of trade.

The principles of mechanism, the knowledge of machinery, should be so thoroughly mastered as to make your minds ready to grasp all the modes of accomplishing any required result so soon as the underlying governing possibilities are presented to the mind. All the various combinations that have been made and classified by teachers of mechanics are as needful to the engineer as the multiplication table, and must be held in mind so as to be called into use automatically, as it were. There are always many ways of accomplishing any required result. The real inventor reaches for the best and the simplest, looking toward efficiency, durability, ease of construction and facility of repair. With this mastery of the principles must be included

the knowledge of physical laws, and the effect of the modes of motion employed, and the ultimate result of motions that for the want of forethought may result in failure.

The problem of water-wheel construction required the best thought of the best man. Governing machinery for the regulation of speed has been made the life study of many men without their nearing the end or reaching perfection, except in special cases, each intricate problem requiring new treatment. I do not say this to discourage you. I mention it to urge you toward the habitual use of your schooling by mental practice, if not by actual use in business. You can, by giving your thoughts to mechanical subjects, keep your memory active, and make yourselves invaluable to those who employ you for your supposed proficiency in knowing how to think, how to plan, how to look ahead, how to be ready for any emergency.

You will appreciate what I now tell you when I come to briefly speak of the genesis of the switchboard, as I have seen the work progress during the last few years. Many years ago, after long and patient thought, I hit upon a happy combination of gearing of a well-known device, called the sun and planet wheel motion, for a particular purpose. The use of wheels thus arranged caused me to utilize the system in many different ways and for many purposes. Within the last month a new use and a modification of the combination has come to my help in one of the most intricate problems I have ever had given me for solution. When you get hold of a good thing hold it fast in your mind; don't do as I did once—forget that you have patented a combination, and, having re-invented the device, try to accomplish the result in some other way, under the impression that your invention has been anticipated by some one, forgetting that that some one was yourself. This happened to me in directing a draughtsman to make an attachment that would permit motion from the driver, but prevent reaction from the driven part of the machine.

COMPARATIVE TEST OF A COMPOUND LOCOMOTIVE AND A SIMPLE LOCOMOTIVE ON THE CENTRAL RAILROAD OF NEW JERSEY.

BY RUSSELL E. TAYLOR, '94; CHARLES C. KENYON, '94; EDWARD D. MATHEY, '94.

THE locomotives tested were excellent examples of the compound and simple types, the compound having been exhibited at the World's Fair, Chicago.

With the exception of the cylinders, the two engines were practically duplicates.

The condition of the rails was good during all the tests, but the weather favored the compound.

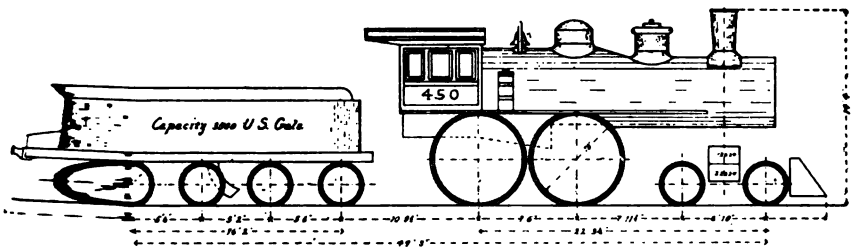
Every facility was extended to enable us to secure complete and accurate data, and it is fitting we should gratefully acknowledge the valuable assistance received from Mr. Thompson, Superintendent of Motive Power of C. R. R., N. J.; from Mr. Vauclain, Superintendent of the Baldwin Locomotive Works, the builders of the engines; from Mr. Custer, the Baldwins' expert on locomotive tests; from Mr. Sinclair, editor of the *Locomotive Gazette*, and from the Thompson Water Meter Company.

The chief facts sought in these tests were the water used per hour per horse-power, the coal used per ton of total train per mile, the evaporation of the respective boilers from and at 212° F. per pound of coal, and the action of the engines under the various conditions existing during the tests.

The results are tabulated in the fol owing summary:

SUMMARY.

	Compound.	Simple.	Per Cent. Favor of	
			Comp'd.	Sim
1. Length of test { During run	37.84 hrs.	37.9 hrs.	.....	.
{ Over night	82.16 "	82.1 "	.....	.
2. Water (lbs.) per hour per indicated H. P.	26.598	28.855	7.83	.
3. Tons of train hauled per mile per lb. of coal	4.573	3.391	15.85	.
4. Evaporation from and at 212° F. per lb. of coal { On run.	7.68	6.244	18.7	.
5. Rate of combustion per sq. ft. of grate surface per hour during run	33.1 lbs.	41.4 lbs.	20.05	.
6. Average boiler pressure (during run)	164.9	157.5	.....	.
7. Greatest H. P. developed during test	1266.99	1233.08	.....	.
8. M. E. P. of greatest H. P.	54.12	60.93	.....	.
9. Speed in miles per hour of greatest H. P.	44.09	57.40	.....	.
10. Grade when greatest H. P. was developed	.6% up.	.2½% up.	.....	.
11. Greatest velocity in miles per hour obtained during test	86.74	83.72	.....	.
12. Coal consumed during test	48,375	60,363	19.86	.
13. Coal consumed in keeping fires over night during test	57,672	8,328	.....	10
14. Total coal consumed during test	9,297	68,691	16.04	.
15. Evaporation fr'm and at 212° F. during test { On run	371603.19	376479.0	.....	
{ Not running.	23736.86	32665.7	.....	27
{ Total	395340.05	409144.7	.....	3

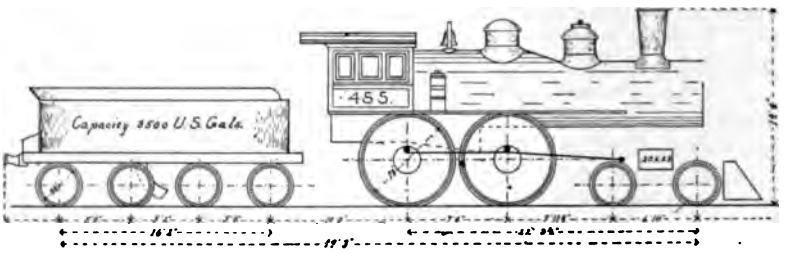


DETAILS OF ENGINE NO. 450. CLASS, VAUCLAIN COMPOUND.

Gauge of Road	4′ 8½″
Builder	Baldwin Locomotive Works, Philadelphia.
Service	Passenger.
Placed on Road	November, 1893.
Fuel	Anthracite Lump Coal
Average Consumption of Coal per 100-miles Run	3½ tons.
Weight on Drivers, running order	87,750 lbs.
" Truck, " "	36,700 "
" Total, " "	124,450 "
" Tender, " "	81,400 "
Total Weight of Engine and Tender, running order	205,850 "
Limit of Height	14′ 6″
" Width	9′ 8″
Driver Brake,	American Outside Equalized, with Westinghouse Fixtures.
Boiler, Type	Extended Wagon Top and Radial Stays.
" Pressure, or Working Pressure	180 lbs.
" Diameter, smallest course outside	57⅜″
" " Extension Front	59 to 59¼″
Boiler Material: Steel throughout; Shell, Dome, Slope, Wagon Top, Side and Backhead Sheets, $\frac{9}{16}$″; Flue Sheets, ½″; Outside Throat Sheet, $\frac{11}{16}$″; Inside Throat Sheet, ½″; Crown Sheet, ⅜″; Fire Box, Side Sheet, $\frac{5}{16}$″; Inside Backhead Sheet, ⅜″; Stay Bolts, 1⅛″ diam.	
Boiler Firebox, length and width inside	131$\frac{15}{16}$″×42⅛″
" " depth, front	65″
" " " back	55¾″
" Tubes, Material and Gauge	Iron No. 12 W. G.
" " Length	11′ 10″
" " Number	250
" " Spaced apart	⅝″
" Outside Diameter	2″
" Water Bars, Number, Length, and Thickness,	Ten (10) 133; ¼″
" Heating Surface Tubes	1530 sq. ft.
" " " Firebox	166 sq. ft.
" " " Total	1696 sq. ft.
" Grate Surface	38½ sq. ft.

Ratio of Grate to Heating Surface . . . . . 1 to
" Flue Opening to Grate Surface . . . . . 1 to
Cylinders, Bore and Stroke . . . L. P. 13"x24" ; H. P. 22"x2
" Spread between Frames (outside) . . . . .
" " " Centers 84½
" " " Valve Stem Centers . . . 50½
Cross Head, Style . . . . . Vauclain Compoun
" Material . . . . . Cast Stee
Connecting Rod : Material and Section Steel ; Rectangular Section
" " Ends . . . . . Strap Ends
" " Length, Center to Center of Journals . . 7' 2½'
Parallel Rod : Material and Section . . Steel, Rectangular Section
" " Ends . . . . . Strap Ends
Crank Pins : Diameter and Lengths, Front; Hub ¼"x8" ; Par. Rod 6"x4"
Con. Rod 5½"x5½".
Crank Pins, Diameter and Lengths, Back : Hub 4¼"x8 ; Par. Rod, 4"x4".
Crank Pins ; Material . . . . . Steel.
Driving Wheel " . . . . . Cast Iron.
" " Center, Diameter . . . . . 72"
" " Axle: Material and Size of Journals . Steel 8"x12"
" " Boxes . . . . . Cast Iron Body.
Dome, Location . . . . . Extended Wagon Top.
" Casing : Style and Material . . . Plain Cast Iron.
Eccentrics . . . . . Cast Iron.
" Throw . . . . . 5¼"
" Straps . . . . . Cast Iron.
Exhaust and Extension Front . Double Nozzle Stand C. R. R. of N. J.
Frame, Main : Material and Section, Hammered Iron, 4"x4" Section.
" Front " " " " 4"x4" Section.
Expansion Pad, Style . . . . . Lap over.
Guides, Style and Material . . . Hammered Iron, Four Bars.
Gauge Cocks . . . . . Three, Self-Cleaning.
Grate, Style and Material, Wrought Iron Water Bars and Pull Out Bars.
Heater Cocks . . . . . For Pass. Car Heating.
Hand Rails . . . . . Polished on Sides and in Front.
Headlight, Style and Size . . C. R. R. of N. J., No. 23" Reflector.
Injectors, Kind . . . . . Two, No. 9 Metropolitan.
" Location . . . . . In Cab on each side.
" Steam Feed and Delivery Pipe . . . Copper.
" Check Valve . . . McDowell Inside Check.
Jacket . . . . . Russia Iron.
Links . . . . . Hammered Iron.
Lagging . . . . . Asbestos Boards.
Oilcup, Cylinders . . . . . Sight Feed.
" Con. Parl. Rods, Guides, Crossh'ds, Exc. Rock, Shaft, Needle Cups.

Pistons, Material and Kind . Cast Iron 4¼" wide with Follower plate.
" Packing Rings . . . Cast Iron, steam packing.
" Rods . . . . . Hammered Iron, 3½" diam.
" " Packing . . . . . Metallic.
Pilot, Material and Style . . . Wood Stand C. R. R. of N. J.
Rocker Arm, Material and Lengths . . . Steel, 8¼" and 8.
Slide Valves, Material and Kind . . Cast Steel Piston Valve.
" " Inside Lap . . . . . None.
" " Outside Lap . . . . . L.P ⅛" H.P⅞"
" " Lead full stroke . . . . L.P.⅜" H.P.⅛"
" " Travel . . . . . 5¼"
Sand Box, Material and Style . . . . Cast Iron Plain.
Springs, Driving, Material, Length, No. of Leaves, 46¾" cent. to cent.; ½"x4"; 17 Leaves.
Springs, Truck, Material, Length, No. of Leaves, 40½" ½x4", 14 Leaves.
" Tender, " " " " 34½", ⅜"x4"; 18 and 20 Leaves.
Stack, Style and Diameter inside . . . Plain, Diam. Ins., 18"
Tires, Material, Inside Diameter, Thickness and Section, Steel 72" ins.diam. 3", M.M. sec.
Truck Engine, Style . . . . . Four Wheeled.
" " Frame Material and Section . 4x1¼" Wrought Iron.
" " Axle; Material, Journals, . Iron 44" cent. to cent.
Tender . . . . C. R. R. of N. J. Stand, Water Scoup.
" Frame. . . . . Iron.
" Cistern . . . . . No. 8 Flange Iron.
" Truck . . . . 4-Wheeled Wrought Iron frame.
" Axle, Material, Journals, Iron, . Journ. 5"x8"; 6' 5" cent. to cent.
" Truck, Material and Section . . . . . 4x2 sec.
Whistle, Kind . . . . . Chime Whistle.



Engines belonging to Class 451–455	Five, 451, 452, 453, 454, 455.
Gauge of Road	4' 8½"
Builder	Baldwin Locomotive Works, Philadelphia.
Service	Passenger.
Placed on Road	August, 1893.
Fuel	Anthracite Lump Coal.
Average Consumption of Coal per 100 mile run	4 tons.
Weight on Drivers, running order	88,400 lbs.
" " Truck " "	37,850 "
" Total " "	126,250 "
" of Tender " "	81,400 "
Total Weight of Engine and Tender, running order	207,650 "
Driver Brake. . . American outside equalized with Westinghouse Fixtures.	
Boiler, Type. . . . . Extended Wagon Top with Radial Stays.	
" Pressure or working pressure	180 lbs.
" Diameter of smallest course outside	60 in.
" " Extension Front	61 in.
" Material, steel throughout, shell, dome, slope, wagon top, side and backhead sheets, $\frac{9}{16}$", Flue sheets, ½", Outside throat sheet, $\frac{11}{16}$," Inside throat sheet ½", Crown sheet $\frac{11}{16}$", Inside backhead sheet, ⅜", Staybolts 1⅛" diam.	
Boiler Firebox, length and width inside	131$\frac{5}{16}$"x42⅛"
" " depth, front	67"
" " " back	57¾"
" Tubes, Material and Gauge	Iron No. 12
" " Length	11' 5"
" " Number	260
" " Spaced apart	⅝"
" " Outside Diameter	2"
" Number of Water Bars, length and thickness.	Ten(10), 133"x¼"
" Heating Surface, flues	1484 sq. ft.
" " " firebox	224 sq. ft.
" " " total	1708 sq. ft.
" Grate Surface	38½ sq. ft.
Ratio of Grate to Heating Surface	1 to 41.7
" " Flue opening to Grate Surface	1 to 8.4

Limit of height of Locomotive . . . . . 14' 6'
" " width " " . . . . . 9' 8"
Cab, width and length . . . . . 9' 6½"x6' 8½"
" height on ends and in the middle . . . . 5' 11"x7' 2½"
Cylinder, Bore and Stroke . . . . . 20"x24"
" Steam ports . . . . . 1½"x20"
" Exhaust port . . . . . 3½"x20"
" Spread between Frames (outside) . . . . 48"
" " " Centers . . . . . 86'
" " " Valve Face centers . . . 76½"
Crosshead, Style . . . . . Alligator.
" Bearing, width and length . . . . 6½"x21"
" Material . . . . . Cast Steel.
Connecting Rod, Material . . . . . Steel.
" " Section . . . . Rectangular Section.
" " Ends . . . Front end solid, Back end Strap.
" " Length center to center of Journals . . 7' 2½"
Parallel Rod, Material and Section . . . Steel, 1 Section.
" " Ends . . . . . Solid.
Rocker Arms, Material and Length: Wrought Iron; Upper Arm, 11¼"
" " " " " " " Lower " 10½"
Slide Valves, Material and Kind: Cast Iron, Richardson balanced.
" " Inside Lap. . . . . None.
" " Outside " . . . . . 1 in.
" " Lead . . . . . ¹/₁₆ in.
" " Travel . . . . . 6½ in.
Sand Box . . . . . Plain Cast Iron.
Springs, Driving, Material, Length, and Number of Leaves: 46¾ C to centre; ½"x4"; 17 Leaves.
Springs, Truck, Material, Length, and Number of Leaves: 40½ C to center; ½"x4"; 14 Leaves.
Springs, Tender, Material, Length, and Number of Leaves: 34½ C to centre; ⅜"x4"; 18 and 20 Leaves.
Stack . . . . . Plain, inside diam. 18"
Tires: Material, Thickness, and Section . . . Steel, 3 in. M. M.
Truck Engine, Style. . . . . Four-Wheeled.
" " Frame: Material and Section . Wrought Iron, 1¾"x4"
" " Axle: Material Journals 5½"x8"; Cent. to Cent. 44", Iron.
Tender . . . C. R. R. of N. J. Standard with Water Scoup.
" Frame . . . . . Iron.
" Cistern . . . . . No. 8 Flange Iron.
" Truck . . . . . Four-Wheeled, Centre Bearing.
" " Axle, Material; Journals 5½"x8"; cent. to cent. 44" Iron.
" " Frame, Material, and Section . . Wrought Iron, 2"x4"
Whistle . . . . . Chime Whistle.

Method of Conducting the Test.

Both engines were put in the best possible condition, *i. e.*, flues cleaned, boilers washed, and overhauled in general, before starting the test.

Each locomotive was given a five days' (120 hours) boiler test, and on two days of the five an engine test was made of each one. The train in both cases consisted of the same cars, so far as was convenient. On the eastward run a car was dropped at Jenkintown, due allowances being made in such cases where car-miles were a factor.

The coal was weighed in small boxes attached to a Fairbanks' platform scales placed at the coal station in the Jersey City yard. The test was commenced in the evening with a good fire by giving the engines a weighed quantity of coal, noting the height of the water in the boiler, and reading the water meters, boiler pressure, and revolution counter attached to the air-brake pump; then allowing the engine to stand until morning. Three-fourths of an hour before starting on the regular run to Philadelphia and return, the coal remaining from over night was weighed, and a weighed quantity given the engines for the day run. The above readings were also taken again. Just previous to starting from the Jersey Central station the following data were noted:

Pressure of steam in boiler, height of water in boiler, which, by the way, was kept about constant during the run, and the same at each reading, temperature of feed water, reading of revolution counter attached to air-brake pumps, and the number of each of the cars hauled.

A revolution counter was also connected with the driving wheels on engine number 455, but such a small amount of slip was noted, that timing the mile posts, and ascertaining the speed by means of a velocity curve, whose ordinates equalled the speed and abscisses the time, was adopted as the best method of ascertaining speed at any period of the run. The water used by the air brake was subtracted from that evaporized in the boiler, during the engine test, to find the water per hour per horse power. It was useless to weigh the ashes, as so much of the coal in the form of cinders was lost through the stack.

Some difficulty was experienced with the water glass on engine number 450, at three different times, compelling on those occasions a reliance on the gauge cocks. The engine test was made from Jersey City to Wayne Junction only and return, this being thought advisable on account of the unfavorable nature of the run from Wayne Junction to Philadelphia, Pa., for such tests. The duty of the four operators was as follows: one timed the stopping and starting of engine, timed the mile posts, and read the vacuum guage at those times; the two operators on the indicators blew out and oiled their indicators at starting, and again after every fifth card. Before taking a card the indicators were allowed to work about ten seconds, to get rid of what steam might have condensed in the pipes connecting indicators with cylinders. The time of taking cards was given by the man in the cab, by ringing a gong placed in the operators' box on front of engine. On the simple engine cards were taken, as nearly as possible, at intervals of two minutes; while on the compound, on account of the necessity of operating two indicators on each side, cards were taken at intervals of three minutes, as nearly as possible. The fourth man's place was in the cab, on the engineer's side, and his duty was to take the throttle readings and the position of reverse lever, the pressure in boiler at the time of taking cards, also the reading of meters at stations. About five minutes after the arrival at Philadelphia, Pa., the engine was backed down about one mile to the round house, and stayed there for two and a quarter hours. At 1.30 the start back to Jersey City was made. After the arrival at Jersey City the remaining coal was weighed, all the above readings made, and a weighed quantity of coal provided for the night. This course was followed each day, and the test finally ended at the same time of day it was begun. The weather, direction of wind and condition of rails, were likewise observed.

DESCRIPTION OF INSTRUMENTS.

The indicators used were of the Ashcroft pattern, having a rachet connected on each drum, for throwing the same in and out of action.

The cylinders were tapped at the upper side of the ends, and, on the simple engine, the ¾-in. diameter pipes which led from these holes connected with the three way-cocks over the center of the steam-chest. On the compound, two indicators on each side of the engine were used, one connecting both ends of the high-pressure cylinders; the other, both ends of the low-pressure cylinders: sharp bends were avoided in each case. The reducing mechanism consisted essentially of three pieces, *i. e.*, one three-foot rod, one link, and one segment. The upper end of the rod was in each case connected with the running board by a stud, about which it was free to vibrate, while the link was connected at one end with the lower extremity of the rod, and at the other end with the cross-head. The running board, although a part of engine frame, was especially braced for the occasion, to insure against any motion relative to the cylinders and guide-bars. The segment was attached to the vibrating-rod, and its center was the stud in the upper part of the rod.

The number of strokes made by the air-pumps was ascertained by having a friction-collar about the piston-rod, and that

in turn connected with a revolution counter attached to the running-board. The height of the water in the boilers was ascertained both by water-gauge and gauge-cocks. The water was measured easily and accurately by attaching Thompson's water-meters to feed-pipes between the tender and the injector, in such a position as to be read from the ground. As these meters are not designed for use with hot water, flap check-valves were placed between the meters and injectors, to guard against steam being forced back through the meter, in case of accident to the injector. The straight gauge, a bent glass tube with a range of about thirty inches, was attached to the front of operator's box and connected to the smoke-box of engine.

The operator's box completely inclosed the lower front end of engine, and was made principally of ¾-in. pine boards, bolted and screwed together and well braced. A feature in its design was the protection afforded to the operators in case of the cylinder head blowing out. The operator's position was over the cylinders while indicating.

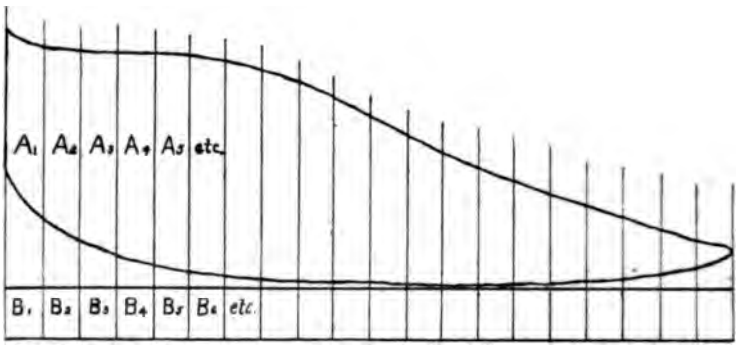
METHOD OF STANDARDIZING INSTRUMENTS USED DURING TEST.

The indicators were standardized in the usual way, by operating them at different pressures, making sure to test them to the maximum pressures to which they would be subjected during the test. The gauge from which the different pressures were read was carefully standardized by the standardizing scales at Stevens Institute of Technology. The scale of the spring was computed by a method devised by Prof. D. S. Jacobus. As the scale of the spring varies for different pressures, it is necessary, for accurate work, to find the maximum and minimum cards for each indicator, and find the average scale of spring between these limits. The method for correcting for all variations in the scales is as follows:

DIVISION OF THE CARD IN ORDER TO OBTAIN THE EQUIVALENT SCALE CORRECTED FOR ALL VARIATIONS IN THE SCALE OF THE SPRING.

Divide the card by a number of ordinates at equal distances apart, as shown in Figure 1. Measure the areas $A_1, A_2,$

etc., included between the forward-pressure line and the atmospheric line, and the areas B_1, B_2, etc., between the back-pressure line and the atmospheric line. Multiply each area by th



scale corresponding with the average pressure, and let SA b the sum of the areas multiplied by the scales for the back pressure line. Then the equivalent scale which the averag height of the indicator card should be multiplied by, in orde to obtain the true mean effective pressure, will be (SA — SB divided by the indicator card.

SPRING A.

Calculations of Equivalent Scale corrected for all variations in the H Scale of the Spring.

Areas measured from line 15 lbs. above atmosphere.

LARGEST CARD OF HIGH-PRESSURE CYLINDER. RIGHT SIDE.

Division of Card.	Area.	Mean Height.	Corresponding Scale.	Area × Scale.	Division of Card.	Area.	Mean Height.	Corresponding Scale.	Area × Scal
A.1.....	.630	1.710	100.78	63.49	B.1....	.320	.869	100.87	32.2
A.2.....	.590	1.600	100.78	59.46	B.2....	.170	.458	102.529	17.4
A.3.....	.580	1.576	100.73	58.42	B.3....	.140	.380	102.38	14.3
A.4.....	.575	1.562	100.69	57.90	B.4....	.140	.380	102.38	14.3
A.5.....	.550	1.494	100.542	55.30	B.5....	.165	.448	102.47	16.9
A.6.....	.480	1.304	100.82	48.39	B.6....	.165	.448	102.47	16.9
A.7.....	.430	1.168	100.89	43.38	B.7....	.210	.570	102.14	21.4
A.8.....	.330	.887	100.843	33.28	B.8....	.230	.625	101.97	23.4
Totals	4.165			419.62		1.540			157

Equivalent Scale = (419.62 — 157.09) ÷ (4.165 — 1.54) = 100.01.

SMALLEST CARD OF HIGH-PRESSURE CYLINDER. RIGHT SIDE.

Division of Card.	Area.	Mean Height.	Corresponding Scale.	Area × Scale.	Division of Card.	Area.	Mean Height.	Corresponding Scale.	Area × Scale.
A-1	.590	1.105	100.52	59.31	B.1.	.33	.618	102.00	33.66
A-2	.580	1.086	100.516	58.31	B.2.	.17	.318	103.83	17.65
A-3	.580	1.086	100.516	58.31	B.3.	.18	.337	103.37	18.61
A-4	.515	.964	100.73	51.88	B.4.	.18	.337	103.37	18.61
A-5	.410	.767	101.13	41.46	B.5.	.23	.430	102.40	23.55
A-6	.170	.637	101.95	17.33	B.6.	.125	.468	102.57	12.82
Total.	2.845			286.60		1.215			124.90

Equivalent Scale = (286.6 — 124.9) ÷ (2.845 — 1.215) = 99.202.

Mean Equivalent = (100.01 + 99.202) ÷ 2 = 99.606.

The water-meters were also very carefully tested at Stevens Institute of Technology, being subjected to the same conditions as when in operation on the engine, *i. e.*, the average head of water was the same, and the water was drawn through by a locomotive injector at about the same average rate as when used on engine.

The steam gauges were tested at Stevens Institute on standardizing scales, by the gravity method.

The exhaust of the air-brake pump was connected with a Wheeler surface condenser, and the water condensed was then weighed, while working under varying conditions, *i. e.*, when brakes are applied suddenly, and when applied moderately.

The planimeters used for finding the areas of the indicator cards were standardized before and during use.

Method of Calculations.

The cards were carefully gone over with a planimeter at least twice, before the final result was accepted; the revolutions of the drivers at the time of taking cards were ascertained by means of the velocity curve previously mentioned. The horse-power of each card having been calculated, a curve was drawn whose ordinates were the horse-powers and abscisses the time the throttle was open.

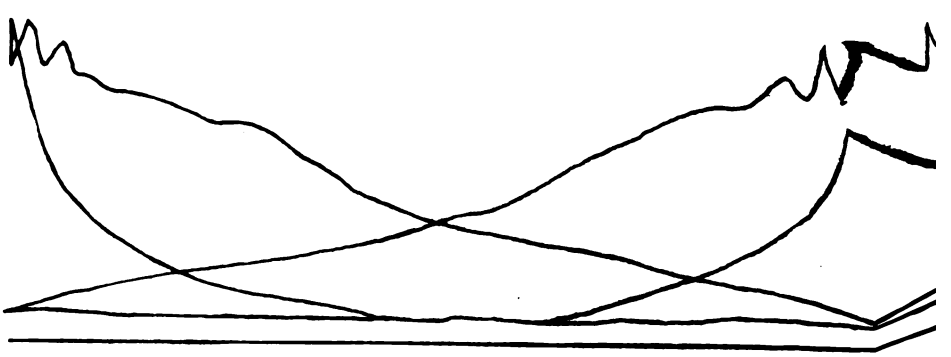
The horse-powers were then multiplied by the time they acted, and this sum divided by the total time the throttle was open during run, gave the average horse-power during the run. The cards having been taken at short intervals, and the run

being quite steady, the error in this method is small. In the boiler test, each day was divided into four parts, *i. e.*, time standing over night, run from Jersey City to Philadelphia, at Philadelphia, and from Philadelphia to Jersey City, in order that a clearer idea of the steadiness in the behavior of the engines might be observed. The final results consisted of the average of these readings.

The horse-power of the boilers was found by considering 34 ½ lbs. of water evaporated, from and at 212° F. per hour. This standard was recommended by the American Society of Mechanical Engineers. The weight of the train being known, the coal per ton per train mile was easily found. Samples of coal were taken each day from different parts of tender, and two analyses of these samples from each engine were made.

HIGH SPEED CARDS FROM LOCOMOTIVE NO. 455 ON TRIP FROM JERSEY CITY TO PHILADELPHIA, APRIL 13, 1894.

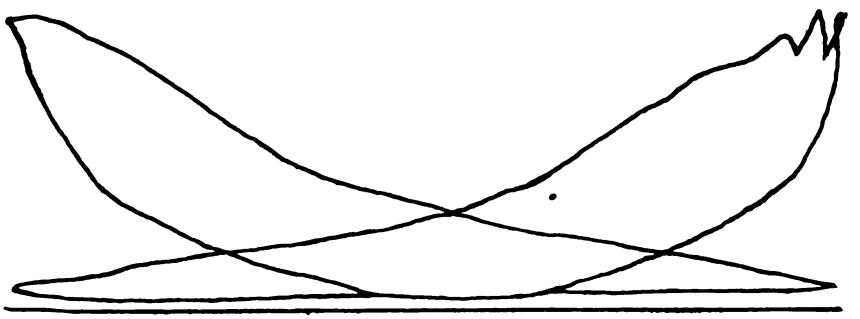
RIGHT SIDE. NO. 9.



M. E. P.—43.174 H. P.—454.07

Scale of spring—99.57

LEFT SIDE. No. 9.



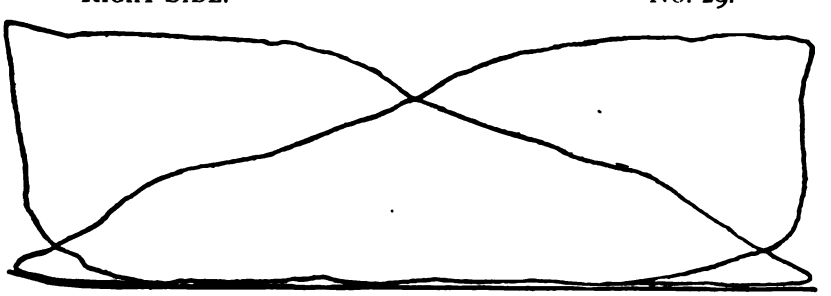
M. E. P.—37.288 H. P.—433.44

Scale of spring—99.17

Boiler Pressure—168 Revolutions per min.—310
Reverse Lever—21 Grade—+32.1
Stroke—24″ Bore—20″

LOW SPEED CARDS FROM LOCOMOTIVE NO. 455, ON TRIP FROM PHILADELPHIA TO JERSEY CITY, APRIL 14, 1894.

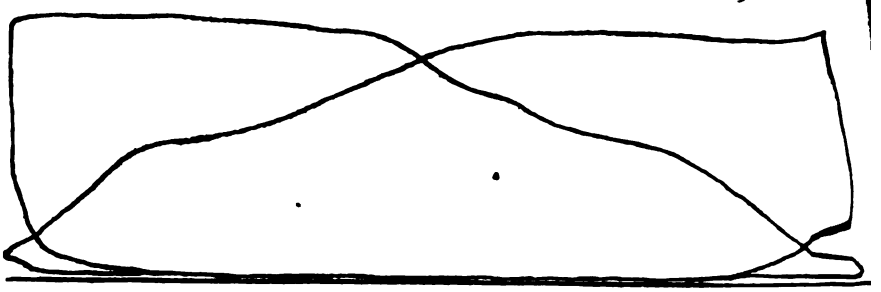
RIGHT SIDE. No. 29.



M. E. P.—87.074 H. P.—39.18

Scale of spring—99.57

LEFT SIDE. No. 29.



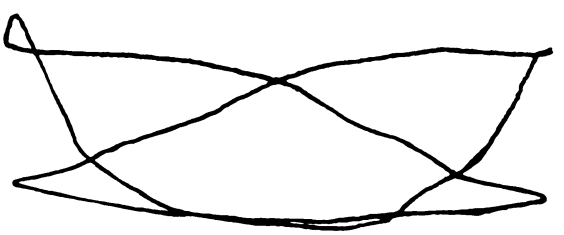
M. E. P.—94.082 Scale of spring—99.17 H. P.—42.33

Boiler Pressure—151 Revolutions per min.—12
Reverse Lever—23 Grade—Level

HIGH SPEED CARDS FROM LOCOMOTIVE NO. 450, ON TRIP FROM JERSEY CITY TO PHILADELPHIA, APRIL 26, 1894.

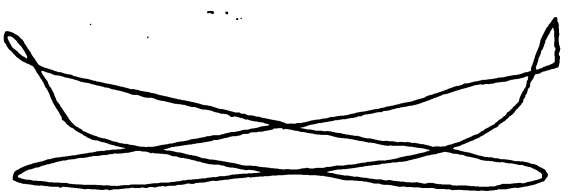
RIGHT SIDE. No. 20.

High pressure.



M. E. P.—55.194 Scale of spring—97.93 H. P.—2

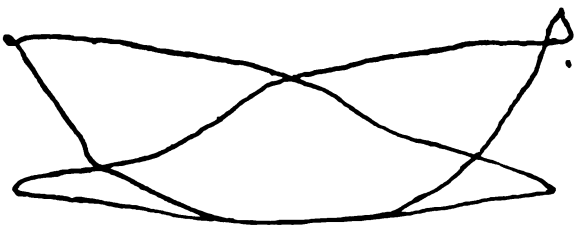
Low pressure.



M. E. P.—19.048 Scale of spring—81.47 H. P.—96.39

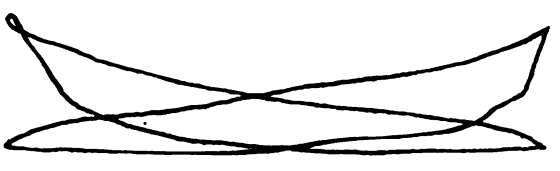
LEFT SIDE. No. 20.

High pressure.



I. P.—46.654 Scale of spring, 99.11 H. P.—247.27

Low pressure.



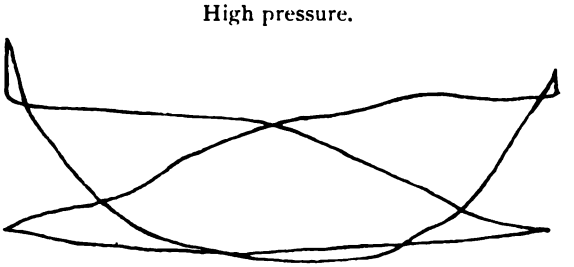
I. P.—18.891 Scale of spring—78 H. P.—286.16

Bore High Press. Cylinder—13″ Boiler Pressure—165
Bore Low " " —22″ Rev. per Min.—342
Stroke " " —24 Reverse Lever—2
Grade—33.79

SPEED CARDS FROM LOCOMOTIVE NO. 450, ON TRIAL TRIP FROM PHILADELPHIA TO JERSEY CITY, APRIL 26, 1894.

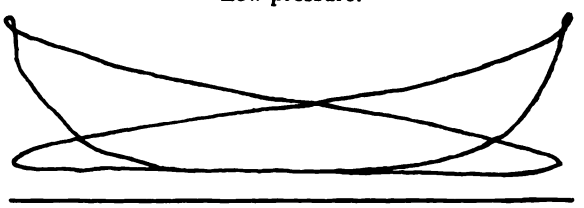
RIGHT SIDE. No. 14.

High pressure.



I. P.—41.914 Scale of Spring—97.93 H. P.—66.26

Low pressure.

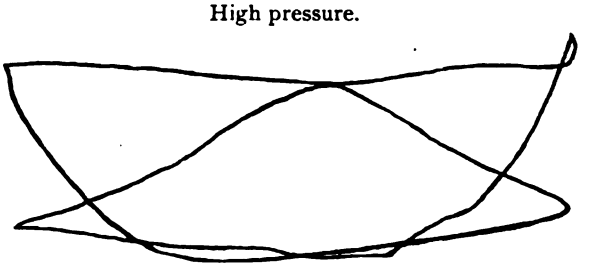


M. E. P.—25.47 H. P.—118.21

Scale of Spring—81.47

LEFT SIDE. No. 14.

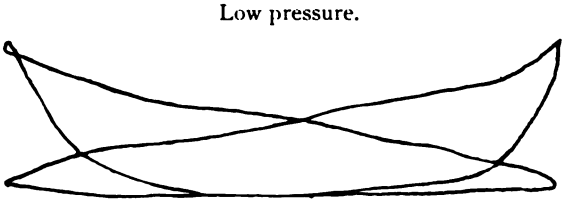
High pressure.



M. E. P.—58.954 H. P.—93.2

Scale of spring—99.11

Low pressure.



M. E. P.—24.93 H. P.—115.68

Boiler Pressure—170.5
Bore of High Pressure Cylinder—13″
Bore of Low Pressure Cylinder—22″
Stroke—24
Rev. per Min.—102
Reverse Lever—3
Grade—Level

F BOILER TEST OF C. R. R. OF N. J. LOCOMOTIVE NO. 450 (COMPOUND).

		Apr. 25	Apr. 26	Apr. 27	Apr 28	Apr. 30	May 1	Total.
MILES		....	183	183	3	183	183	915
		H. M. S.	H. M. S.	H. M. S.	H. M. S.	H. M. S.	H. M. S.	H. M. S.
.....	To Philadelphia	.....	2-00-40	2-07-50	1-56-40	2-02-55	2-01-16	10-09-21
	At Philadelphia	.....	3-18-20	3-12-05	3-19-16	3-17-19	3-16-05	16-23-05
	To Jersey City	.....	2-12-15	2-18-25	2-16-15	2-14-20	2-18-10	11-19-35
	Over night	16-28-00	16-27-25	16-26-00	16-25-33	16-22-53	.....	82-09-51
.....	On trip	.....	9230	9763	10271	9534	9577	48375
	Over night	1391	1675	1955	2158	2118	.....	9297
ated for by	To Philadelphia	.....	30652.72	32241.12	32234.97	24058.72	31219.04	150407.2
	At Philadelphia	.....	2026.5	1393.26	1836.57	8366.24	1203.27	7825.8
. .....	To Jersey City	.....	26345.28	29765.1	32488.29	31519.34	31981.65	152100.00
	Over night	4276.45	1647.58	3799.80	4045.32	6649.65	.....	20418.35
: of feed	To Philadelphia	.....	60°	61.5°	62°	60°	61°	Av. 60.9°
.....	To Jersey City	.....	62°	63.5°	63°	62°	62°	Av. 62.5°
ustion per	On trip	.....	239.74	250.49	266.78	247.64	248.75	250.78
ate area...	Over night	33.53	43.507	50.78	56.05	55.01	.....	47.775
ustion per	On trip	.....	5.44	5.76	6.056	5.62	5.65	5.705
at'g surface	Over night	.84	.99	1.15	1.27	1.25	.....	1.10
er pressure	On trip	.....	166	164.5	165	164	165	164.9
	Over night	110	110	110	110	110	110	110.0
which wo'd ed if temp. er =212° & porated at r pressure.	On trip	.....	68212.69	73174.93	76704.3	73767.51	74285.51	.....
	Over night	.....	.....	.....	.....	.....	.....	.....
	Total for five days	.....	.....	.....	.....	.....	.....	23612.47
which wo'd ed if temp. er =212° & porated at ic pressure,	On trip	.....	69161.32	74147.11	77887.41	74926.04	75431.31	371603.19
	Over night	.....	.....	.....	.....	.....	.....	.....
	Total for five days	.....	.....	.....	.....	.....	.....	23736.86
evaporated per hr. of total time if temp. of feed = 212° & water at atmospheric pressure		.....	.....	.....	.....	.....	.....	9318.03
evaporated per hr. of total time at J. C. if temp. of feed = 212° & orated at atmospheric pressure.		.....	.....	.....	.....	.....	.....	288.84
34.5 lbs of orated.....	During run	.....	.....	.....	.....	.....	.....	241.1
	Over night	.....	.....	.....	.....	.....	.....	8.37
ain back of	Jersey City to Phila.	.....	263440	263440	318840	318840	263440	285600
	Phila. to Jenkintown	....	320900	320900	376300	376300	320900	343060
	Jenkintown to J. C.	.....	266900	266900	322300	322300	266900	289060
of train...	Jersey City to Phila.	.....	469290	469290	524690	524690	469290	491450
	Phila. to Jenkintown	.....	526750	526750	582150	582150	526750	548910
	Jenkintown to J. C.	.....	472750	472750	528150	528150	472750	494910
per mile per pound of coal.....		.....	.02540	.02407	.025502	.02748	.02454	.02541
								Total.
l by air	To Philadelphia	.....	839.09	1045.43	532.51	917.28	400.46	3734.77
	At Philadelphia	.....	301.4	322.42	335.38	32.83	231.70	1523.73
	To Jersey City	.....	814.75	1042.69	740.6	502.70	734.40	3835.14
	Over night	126.86	245.26	390.90	340.70	552.81	.....	1656.59
by injector.	To Philadelphia	.....	197.6	209.8	126.7	.....	.....	.....
	To Jersey City	.....	181	172.9	144.8	.....	.....	.....
from 212° ic pressure of coal....	On trip	.....	7.49	7.6	7.58	7.85	7.88	Av. 7.68
	Over night	.....	.....	.....	.....	.....	.....	.....
	Total for five days	.....	.....	.....	.....	.....	.....	Av. 2.55

Data of Boiler Test of C. R. R. of N. J. Locomotive No. 455 (Single).

		Apr. 9	Apr. 10	Apr. 12	Apr. 13	Apr. 14	Total.
Date of Test							
Distance		180	180	180	180	180	900
Time of test	To Philadelphia	H. M. S. 2-03-50	H. M. S. 2-16-45	H. M. S. 2-00-32	H. M. S. 1-59-05	H. M. S. 1-57-02	H. M. S. 10-17-17
	At Philadelphia	3-14-50	3-02-30	3-17-30	3-18-10	3-21-10	16-12-14
	To Jersey City	2-16-03	2-18-00	2-18-04	2-18-46	2-18-03	11-28-56
					Total time		37.96 hrs.
	Over night	16-26-17	16-22-45	16-23-54	16-24-42	16-23-38	82.1 hrs.
Fuel used	On round trip	12821	12578	11656	11286	12022	60363 lbs.
	Over night	1432	1813	1793	1665	1625	8328 lbs.
Water accounted for by meters	To Philadelphia	30253.64	30316.8	7853.56	29243.08	27853.56	145520.6
	At Philadelphia	2021.12	1263.2	2022.08	2905.36	1991.12	10202.6
	To Jersey City	33790.6	31137.82	31480	31580	33411.64	161400.06
	Over night	4105.4	7036.02	6000.2	4800.13	5485.43	27427.18
Temperature of feed water	To Philadelphia	44	44	40.5	43.5	48	Av. 44
	To Jersey City	45.2	44	40.5	48.5	48	Av. 45.2
Rate of combustion per sq. ft. of grate surface	On round trip	333.01	326.7	302.8	293.41	312.26	Av. 313.03
	Over night	37.19	47.09	46.57	43.24	42.21	Av. 43.21
Rate of combustion per sq. ft. of heating surface	On round trip	7.56	7.36	6.81	6.607	7.03	Av. 7.07
	Over night	.838	1.061	1.049	.974	.951	Av. .974
Boiler pressure	To Philadelphia	162.9	146.9	172.3	165.2	161.5	.....
	To Jersey City	153.9	155.9	161.0	149.7	145.0	.....
	Over night	110	110	110	110	110	Av. 110
	On round trip	158.4	151.4	166.0	157.4	153.4	Av. 157.5
Weight of H_2O which would have been fed if temperature of feed water was 212° and evaporated at actual boiler pressure	On trip	77342.6	73317.1	72031.19	74498.5	73756.86	370946.3
	Over night	.....	.....	.....	.....	Total..	32199.4
Weight of H_2O which would have been fed if temperature of feed water was 212° and steam evaporated at atmospheric pressure	On trip	78485.64	74446.05	73196.9	75518.1	74832.2	376479
	Over night	.....	.....	.....	.....	Total..	32665.3
Weight of water evaporated per hour of total running time if temperature of feed water is 212° and steam evaporated at atmospheric pressure		.....	.....	.....	.....	.....	9933.4
Weight of water evaporated per hour of total time of standing at Jersey City over night if temp. of feed water is 212° and steam evap. at atmospheric pres'e		.....	.....	.....	.....	.....	392.3
H. P., *i. e.* 34.5 lbs. evaporated.	During run	.....	.....	.....	.....	.....	287.9
	During night	.....	.....	.....	.....	.....	11.4
Weight of train back of tender.	Jersey City to Phila.	241390	316890	256890	256890	312290	1384350
	Phila. to Jenkintown	300850	316350	316350	316350	371750	1621650
	Jenkintown to J. C.	246850	262350	262350	262350	317750	1351650
Total weight of train	Jersey City to Phila.	449040	524540	464540	464540	519940	2422600
	Phila. to Jenkintown	508500	524000	524000	524000	579400	2659900
	Jenkintown to J. C.	454500	470000	470000	470000	525400	2389900
Tons per mile per pound of coal		.0123	.0197	.0206	.0206	.0216	
Water used by air pump	To Philadelphia	843	668.21	668.21	668.21	668.21	Total 3515.84
	At Philadelphia	289.28	289.28	289.28	289.28	289.28	1446.4
	To Jersey City	743.52	660.06	743.52	743.52	743.52	3636.14
	Over night	404.07	404.07	404.07	404.07	404.07	2020.35
Water wasted by injector	To Philadelphia	72.4	217	181	217.2	235.3	922.9
	To Jersey City	162.9	181	181	235.3	162.9	923.1
Water evaporated from and at 212° and at atmospheric pressure per pound of coal	On run	6.12	5.91	6.28	6.69	6.22	Average
	Over night	.....	.....	.....	.....	.....	

Data of Test on Engine No. 455 on the Run from Jersey City to Philadelphia, Pa., April 13, 1894.

Number of card.	Time, A. M.	Boiler Pressure.	Throttle.	Reverse Lever.	Vacuum.	Rev. per Minute.	Grade.	M. E. P.		Horse-Power.			Time H.P Acted. Minutes.	H.P. x Time.	Remarks.
								Left Side.	Right Side.	Left Side.	Right Side.	Total.			
*1	8 16	166.6	5-6 full.	21	10	108	Level	52.254	45.055	209.68	182.47	392.15	3.000	1176.45	*Injector applied.
2	8 18	150.0	Full.	"	10	208	-3.1	52.302	49.188	407.95	383.66	791.61	2.000	1583.22	
3	8 20	146.6	"	"	7½	238	-3.1	39.548	39.061	201.89	192.37	394.26	2.830	1115.57	
*4	8 25	175.0	"	"	7	175	Level	70.866	66.921	465.09	409.10	974.19	2.000	1748.38	
5	8 28	156.6	"	22	....	26	+17.2	73.855	75.165	72.01	73.28	145.29	2.410	350.14	
6	8 32	175.0	"	"	9	66	+17.2	78.624	56.456	194.24	139.72	333.96	1.333	444.16	
7	8 34	170.8	"	"	11	176	+1.7	64.797	62.789	427.66	414.41	842.07	2.000	1684.14	
*8	8 36	166.6	"	21	9	236	+32.1	49.873	45.185	441.34	399.89	841.18	2.000	1682.36	
9	8 38	168.0	"	"	8	281	+32.3	46.069	43.124	517.09	454.96	972.05	2.000	1944.10	
01	8 40	170.5	"	"	8	269	-21.2	53.433	47.117	539.03	475.32	1014.35	2.000	2028.66	
11	8 42	102.4	"	"	....	288	-18.4	39.946	33.645	431.41	430.25	861.66	2.166	1861.17	
*12	8 45	162.4	"	"	7	26	-18.4	68.983	63.376	67.25	68.131	135.38	1.166	151.05	
13	8 47	155.4	"	"	7	160	Level	44.428	40.505	267.77	243.03	510.80	3.166	1614.12	
14	8 50	156.6	"	"	6½	257	-12.5	52.630	55.231	507.24	533.31	1040.55	1.500	1560.82	
*15	8 56	156.6	"	"	6½	30	-13.2	76.182	70.80	85.70	83.34	169.04	1.000	169.04	
16	8 58	155.4	"	"	7	132	+13.2	55.287	49.307	254.06	234.07	488.13	2.000	976.26	
17	9 00	156.6	"	"	7½	227	Level	49.772	43.263	423.78	368.29	792.00	2.000	1584.00	
18	9 02	152.0	"	"	7½	258	+26.4	43.803	40.903	423.71	395.70	819.49	2.000	1638.98	
*19	9 04	145.4	"	"	7	276	-6.07	41.036	36.433	424.72	384.37	819.09	2.000	1638.18	
20	9 06	142.4	"	"	6½	267	+6.07	40.551	35.098	406.04	351.44	767.48	2.000	1534.96	
21	9 08	140	"	"	6½	281	+6.7	38.112	31.404	401.62	330.95	741.57	2.000	1483.14	
22	9 10	140	"	"	6½	272	+36.96	38.408	32.101	391.76	327.43	719.19	2.000	1438.38	
23	9 12	135	"	"	5	258	+36.96	41.764	34.172	404.15	330.78	734.93	2.000	1469.86	
24	9 14	130	"	"	5	232	Level	40.382	32.798	351.32	285.34	636.66	3.41	2111.01	
25	9 18	141	"	"	6	200	+7.39	44.210	37.458	331.48	280.94	612.42	1.08	661.41	
26	9 20	131	"	"	5½	223	-1.9	36.911	32.890	235.60	193.31	428.91	2.000	857.82	
27	9 22	127	"	"	5½	280	+36.94	30.544	26.794	320.71	281.34	602.91	2.500	1334.61	
28	9 29	144.5	"	"	5½	124	+29.04	58.977	51.418	274.24	289.08	513.32	.500	256.66	
29	9 31	138	"	"	7½	153	-7.92	47.265	42.954	273.21	240.47	519.68	2.000	1039.32	
30	9 33	138	"	22	7	172	-21.12	50.457	43.841	325.45	280.77	606.22	2.000	1212.44	
31	9 35	129	"	"	7	206	-15.84	39.747	35.537	307.44	274.88	582.32	2.750	1601.48	
32	9 39	150	"	21	7	251	+36.96	45.282	38.683	246.24	363.12	609.36	1.750	1066.38	
33	9 41	141.8	"	"	5½	245	+22.70	43.918	35.676	404.15	327.79	731.94	2.000	1463.38	
34	0 43	132	"	"	6½	253	+22.70	41.463	35.298	394.40	334.91	729.31	3.000	2669.27	
35	9 47	146.8	"	22	7½	226	Level	38.305	41.700	409.38	353.41	762.79	.833	633.11	
36	9 49	138	"	"	7	229	-10.36	48.662	42.258	417.91	362.91	780.81	3.500	2732.83	
37	9 53	154.4	"	21	8½	224	.....	53.591	49.765	450.16	418.03	868.19	1.580	1371.74	
38	9 55	143.8	"	"	7½	165	.....	39.648	35.386	245.34	218.97	464.32	2.250	1045.31	
39	9 57	146.8	"	"	8½	260	.....	50.229	46.290	489.73	461.33	951.06	1.410	1340.99	

(Total H. P. + Time) ÷ Total Time = Average H. P. during run; ∴ 52271.300 ÷ 79.62 min. = 656.5 = Average H. P. during run.

THE CHEMICAL AND PHYSICAL EXAMINATION OF PAPER.

BY. PROF. THOMAS B. STILLMAN.

(Continued from p. 176.)

2. *Determination of Free Acids in the Paper.*

Free acids in the paper may be :

1st. Chlorides, from the hypochlorites used in the bleaching, and which have not been removed by the "anti-chlor."

2d. Sulphuric Acid, from acid alums used in the sizing.

Free acids are exceedingly injurious to the paper, producing gradual deterioration in the breaking strength, and also producing brittleness.

The amount of chlorides can be determined as follows :

Take 0.5 gramme of the paper, cut into small portions, and digest with 50 c.c. of boiling distilled water for two minutes, then filter. The filtrate is acidified with a few drops of nitric acid, and the amount of Cl determined by a $\frac{1}{10}$ normal $AgNO_3$ solution.

The free sulphuric acid determination requires the determination of the combined sulphuric acid in the alum, since in the titration with soda solution the combined acid, as well as the free, is indicated. The combined acid is determined indirectly and then subtracted from the total acid, the difference being the free acid, thus : If the alum used is potash alum, the percentage of potash should be determined, and then the amount of sulphuric acid and alumina calculated from the formula of the alum (anhydrous) $K_2Al_2(SO_4)_4$.

If soda or ammonia alum be used, the determination of the soda, or ammonia, will be required, as in the potash alum. Where no clay has been used in the paper, the alumina can be determined* instead of the other base, and the sulphuric acid necessary to form the alum calculated ; this latter is then deducted from the total acid. Total acid is thus determined.

* Basic sulphate of alumina forms an exception. *Ferguson*, "Basic Sulphate of Alumina," *Journal Amer. Chem. Society*, XVI., p. 153.

Two grammes of the paper are cut into small pieces and di-
sted with 200 cc. of boiling distilled water for three minutes,
en filtered and a few drops of solution of litmus added. A
lution of $\frac{1}{10}$ normal soda is gradually added from a burette,
til the red color of the solution turns to blue, when the
ıount of alkali used is noted and calculated to sulphuric acid.

From the total amount of sulphuric acid is subtracted the
mbined sulphuric acid already determined in two grammes
paper. This latter amount is found by determination of
her of the bases, alumina, potash, soda, or ammonia, and cal-
lation of the required acid necessary to form the alum used
the paper.

If sulphate of alumina, $Al_2(SO_4)_3$, be used instead of
ım, then the free acid and combined acid will be the same in
ıount, since sulphate of alumina is an acid salt, and titration
th the soda solution will give the amount directly.

3. *Determination of the nature and amount of sizing used.*

A paper sized with rosin, when extracted with absolute
:ohol gives a solution which, poured into excess of water,
:lds a milky turbidity due to precipitated rosin.* Another
;t is based on the Raspail reaction, rosin giving, with sugar
lution and sulphuric acid, a violet-red color. The sugar may
omitted, as enough is formed for the reaction by the action
the sulphuric acid on the cellulose of the paper.

The presence of animal size is detected by treating the
ıueous extract of the paper with tannin. The following fun-
ımental distinction between papers sized with rosin and gel-
in is found to exist. In the former the rosin is distributed
ıiformly throughout the substance of the paper, while in the
tter, whether the sizing has been performed in the pulp or
ıeet, it is always found exclusively on the surface of the fin-
ıed product. This peculiar property of gelatin can be shown
saturating a plaster-of-Paris slab with gelatin solution col-
ed suitably, and breaking it when dry, on which it will be
ınd to be colored to a trifling depth, the inner part being
ite. On these facts the following test is based : A half-sheet
paper is repeatedly crumpled and unfolded, and, when the

* W. Hertzberg. *Mitt. König. Tech. Versuchs*, III., p. 107. *Journal Chem. Industry*, IX., p. 99.

surface has been thoroughly chafed, is smoothed out and written upon: if it is sized with rosin, the inscribed characters are but little blurred; while, if animal size has been used, they run freely, and are visible from the opposite side of the sheet. Leonhardi has modified this test, removing the doubtful element introduced by the manual use of pen and ink. A pipette, of which the exit is 10 c.m. above the paper, and which delivers drops weighing 0.03 grm. each, is filled with a solution of ferric chloride containing 1.531 per cent. of iron. A single drop is allowed to fall and to remain on the paper for the same number of seconds that 1 sq.m. of the paper weighs in grammes, when it is removed by blotting paper, and the under side of the paper brought in contact with a plug of wadding wet with a weak solution of tannin: the production of a black color proves the iron solution to have penetrated, and, therefore, shows the sizing to be of animal origin.

Schuman's method for the determination of rosin in paper is as follows: 2 grammes of the paper are cut into fine pieces and digested below boiling fifteen minutes with a five per cent. solution of sodium hydrate, and filtered.

The filtrate is made acid with dilute sulphuric acid, the rosin separating and rising to the surface of the liquid. This latter is filtered upon a weighed filter, dried at 100° C. to constant weight, and its weight carefully determined.

Starch was used, formerly, as a sizing for paper, but in recent years it has been largely replaced by rosin size. It can be detected as follows:

The paper is cut into small portions and is digested with boiling water for fifteen minutes, then filtered. To the filtrate is added a drop of a dilute solution of iodine. A blue coloration is indicative of the presence of starch.

The quantitative determination is dependent upon the conversion of starch into glucose by means of dilute H_2SO_4, and estimation by means of Fehling's solution.

10 to 15 grammes of the paper are digested with 250 cc. of distilled water, to which has been added 2 per cent. of sulphuric acid. Two or three hours' heating at 100°C. is sufficient to convert the starch into glucose, the exact point being determined by taking a drop of the solution and adding thereto one drop

of the dilute iodine ; if no blue color is shown, the conversion is complete.

The solution is now made alkaline with soda, diluted with water to 500cc., and two samples each of 150 cc. taken, filtered, washed well and treated with Fehling's solution,* as usual in the determination of sugars. Sadtler states as follows regarding this test :

"In carrying out the gravimetric method the Fehling's solution remains in excess (indicated by the blue color of the solution after boiling), while the cuprous oxide is carefully filtered off and further treated."

The procedure is as follows: †

Sixty cubic centimetres of the mixed Fehling's solution and thirty cubic centimetres of water are boiled in a beaker, and the solution containing the maltose added thereto and the mixture again boiled, It is then filtered with the aid of a filter-pump, upon a Soxhlet filter (asbestos layer in a tared funnel of narrow cylinder shape), quickly washed with hot water, and then with alchol and ether, and dried. The asbestos filter, with the cuprous oxide, are now heated with a small flame, while a current of hydrogen is passed into the funnel, so that the precipitate is reduced to metallic copper. It is allowed to cool in the current of hydrogen, placed for a few minutes over sulphuric acid and then weighed.

Determination of the Ash.

Three grammes of the paper are transferred to a weighed platinum crucible and ignited until all carbonaceous matter is consumed. The amount of ash is indicative of the use, or not, of mineral filling, such as Carolina koalin, to increase the weight of the paper. After the correct determination of the amount of the ash, it should be transferred to a 3″ porcelain capsule, and the following scheme used for its analysis:

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* Tollens' formula for Fehling's solution is as follows:—34.639 grms. crystallized copper sulphate are dissolved in 500 cc. H_2O. 173 grms. Rochelle salts and 60 grammes sodium hydrate are dissolved together in 500cc. of H_2O. Equal volumes of these solutions are mixed when required for use. 10 cc. of this Fehling's solution correspond to 0.0807 grm. maltose —or 0.0765 grm. starch.

† Industrial Organic Chemistry, *Sadtler*, p. 152.

Transfer to a 3" porcelain capsule, add 15 cc. HCl, 10 cc. HNO_3, and evaporate to dryness. Add 10 cc. HCl, 50 cc. H_2O, boil and filter, and make filtrate up to 250 cc. at 15° C. and thoroughly mix.

RESIDUE. Dry, ignite and weigh.
If clay or calcium sulphate be present, fuse with 8 times volume of Na_2CO_3 in platinum dish. Dissolve in 100 cc. H_2O, acidify with HCl, and evaporate to dryness; add 10 cc. HCl, 50 cc. H_2O, boil and filter.

RESIDUE, Dry, ignite, and weigh as SiO_2

SiO_2

FILTRATE. Make alkaline with NH_4HO + NH_4Cl, boil and filter.

RESIDUE, Al_2O_3. Dry, ignite, and weigh as Al_2O_3.

Al_2O_3

FILTRATE. Add solution of ammonic oxalate, set aside 4 hours, then filter.

RESIDUE, CaC_2O_4; dry, ignite, and weigh as CaO and calculate to $CaSO_4$.

$CaSO_4$

FILTRATE. Add solution Na_2HPO_4; stir well, set aside 2 hours, then filter, dry, ignite, precipitate, and weigh as $Mg_2P_2O_7$, and calculate to $MgSiO_3$.

$MgSiO_3$

Take 100 cc for determination of soluble bases, Al_2O_3, Fe_2O_3, CaO, MgO, etc. Add ammonic hydrate and ammonic chloride in slight excess, boil and filter, wash well.

RESIDUE, Al_2O_3, Fe_2O_3. Dry, ignite, and weigh as Al_2O_3 if the residue is white; if red, as Al_2O_3, Fe_2O_3. To separate Fe_2O_3 from Al_2O_3, use the method of fusion with KHO in a silver dish. The aluminum forms soluble potassium aluminate, the iron remaining as insoluble Fe_2O_3.
Treat with water, filter, wash well, dry, ignite, and weigh as Fe_2O_3, and subtract weight from total of Al_2O_3, Fe_2O_3. The difference is Al_2O_3.

Sol. Al_2O_3 Fe_2O_3

FILTRATE. Add solution of ammonic oxalate in slight excess; set aside 4 hours, filter, wash well.

RESIDUE, CaC_2O_4. Dry, ignite and weigh as CaO.

CaO

FILTRATE. If only Magnesia is to be determined in this solution, add sol. Na_2HPO_4, set aside 2 hours, filter, dry, ignite and weigh as $Mg_2P_2O_7$. If, however, silicate of soda has been found, then proceed to determine the MgO and Na_2O, as follows: Evaporate the filtrate from the CaC_2O_4 to dryness in a platinum dish, with H_2SO_4, ignite to constant weight. This gives the weight of Mg_2SO_4 and Na_2HPO_4. Dissolve in H_2O acidify with HCl, make alkaline with ammonic hydrate, and precipitate the Mg with Na_2SO_4, filter, dry, ignite, and weigh as $Mg_2P_2O_7$, and calculate to $MgSO_4$. This latter weight subtracted from total $MgSO_4$ and Na_2SO_4, gives the weight of Na_2SO_4. The latter is calculated to Na_2O.

MgO

Na_2O

SO_3

Take 50 cc., bring to a boil, add slight excess of solution of barium chloride, and set aside 4 hours. Filter, wash well, dry, ignite and weigh as $BaSO_4$, and calculate to $CaSO_4$.

$CaSO_4$

It is always advisable to test some of the ash, before its alysis, by fusing a portion on charcoal with sodium carbon- e. By this means, lead or chromium can be detected, and en properly separated in the analysis of another portion of e ash. If clay, in appreciable quantities, is found, it will be cessary to add ten per cent. of its weight as water, since ost clays contain from eight to twelve per cent. of water, ich, in the above instance, would have been driven off dur- g the ignition of the paper to determine the per cent. of ash. much iron be found, Prussian blue, Indian red, Venetian red, ochre may have been used. If the color of the ash is blue, tramarine is present; if white, silica, or a fine quality of clay, calcium sulphate, or agalite* may be present; the chemical alysis readily showing the one used as a filler.

If the ash found is very small in amount, it will be neces- ry to subtract the amount of ash corresponding to the variety fibre or pulp with which the paper is made, to exactly de- rmine the amount of ash belonging to the added materials.

ASH IN COMMERCIAL PULPS.

	Per cent.		Per cent.
Sulphite,	0.48	Ground wood (fir),	0.70
Sulphite, bleached,	0.42	Ground wood (aspen),	0.44
Soda,	1.34	Ground wood (lime),	0.40
Soda, bleached,	1.40	Linen	0.76
Straw,	2.30	Linen, bleached,	0.94
Straw, bleached,	1.34	Cotton,	0.41
Ground wood (pine),	0.43	Cotton, bleached,	0.76

ASH IN FIBERS.

	Per cent.		Per cent.
Cotton,	0.12	Fine Flemish flax,	0.70
Italian hemp,	0.82	China grass,	2.87
Rhea,	5.63	Jute,	1.32
Best Manilla hemp,	1.02	Esparto,	3.50–5.04
Sulphite fiber,	0.46	Soda fiber,	1.00–2.50

[TO BE CONTINUED.]

* A variety of talc—silicate of magnesia—in a finely powdered con ion; it has a very extensive use as paper filler.

RAILROADS AND CANALS.

CORRESPONDENCE OF JOHN STEVENS DURING 1811–1812.

In 1852 there was published a pamphlet containing the correspondence of Mr. John Stevens on the above subject, together with some related documents. This pamphlet has, of course, long since become rare and practically unattainable, after the manner of pamphlets generally.

The views expressed by Mr. Stevens in this correspondence, to use the words of one of the most prominent mechanical engineers of the present time, "then so far in advance of contemporaneous public opinion, have been so conclusively established by the experience of the world, that it becomes a duty we all owe to his memory to make this fact known as extensively as possible."

The matter having been brought to the attention of the editors of the INDICATOR, by a letter from which the above quotation is made, they have concluded to place the entire contents of the pamphlet mentioned (of which a copy has been, with much difficulty, secured) in more permanent form, by printing it entire in the pages of the INDICATOR.

DOCUMENTS
Tending to
PROVE THE SUPERIOR ADVANTAGES
OF
RAILWAYS AND STEAM CARRIAGES
OVER
CANAL NAVIGATION.

Printed by T. & J. Swords,
No. 160 Pearl Street, New York.
1812.
Reprinted by Stanford & Swords, 137 Broadway,
1852.

PREFACE.

The pamphlet, here reproduced forty years after its first appearance, will now, in the light of its fulfilled and realized

speculations, be read with a degree of interest and admiration which, at the period of its publication, it failed to attract.

Having, while recently preparing a paper on the growth of the city of New York during the last half century, been led into some investigations as to the pioneers in the construction of steamboats and railroads, and remembering something of a pamphlet about railroads, published many years before, by Col. Stevens, of Hoboken, I long sought for a copy of it, and, at last, one was found among the bound pamphlets of the New York Historical Society Library.

Upon being informed of its existence, the sons of the ingenious author obtained permission to have it copied, determining to reprint it in honor of their distinguished father, and they placed the MS. in my hands for that purpose.

It seemed altogether fitting that the direct successors of the publishers, who had given the original to the world, should be invited to print this edition; and accordingly it bears the imprint of Stanford & Swords, 137 Broadway, 1852, as its original bore that of T. & J. Swords, 160 Pearl St., 1812: thus marking at once perpetuity and change.

Of the author of this pamphlet, Col. John Stevens, of Hoboken, a fitting memorial is yet to be written, for he was emphatically, a benefactor of his country and his race. Born to affluence, his whole life was devoted to experiments, at his own cost, for the common good.

Mr. Stevens was a native of this city, where he was born in the year 1749. His grandfather, John Stevens, a native of England, came to the colony of New York early in the last century, as one of the law officers of the crown. His father, John Stevens, became a resident of New Jersey, and married Elizabeth Alexander, descended from one of the original proprietors of New Jersey, and was himself much in public stations there, and for a time Vice-President of the Council.

John Stevens, of whom we are treating, though born in this city, was a Jersey man by residence, and eventually by his marriage with Rachel Cox, daughter of John Cox, of Bloomsbury, N. J., who also for many years was Vice-President of the Council of that State. Mr. Stevens was himself for several years treasurer of the State.

Mr. Stevens' attention was first turned, or rather the bent of his genius was developed and directed towards mechanics and mechanical philosophy, by the accident of seeing, in 1787, the early, and as now may be said imperfect, steamboat of John Fitch, navigating the Delaware river. He was driving in his phaeton on the banks of the river, when the mysterious craft, without sails or oars, passed by; Mr. Stevens' interest was excited; he followed the boat to its landing, familiarized himself with the design and the details of this new and curious combination, and from that hour became a thoroughly excited and unwearied experimenter in the applications of steam to locomotion on the water, and subsequently on the land.

Having been brought, by close family connection, into intimacy with Robert R. Livingston, (the Chancellor of this State, who married the sister of Colonel Stevens), he induced Mr. Livingston to join him in these investigations, and they were persevered in at great cost and with little immediate success till Chancellor Livingston, in 1801–2, was sent as minister to France.

So much, however, was the Chancellor encouraged by the experiments then made, that as early as 1798, he obtained from the Legislature of New York, an exclusive grant for the use of steam on the waters of New York. This, however, became forfeit by the failure to avail within the limited time of its privileges.

But previously to the act of '98, the Legislature of New York had, as early as 1787, granted successively to James Rumsey and to John Fitch the exclusive right to navigate the waters of the State with steam-propelled vessels; and on the 5th of January, 1789, John Stevens petitioned the Legislature for a like grant—nothing having resulted from the preceding grants. Mr. Stevens in his petition says that, "to the best of his knowledge and belief, his scheme is altogether new, and does not interfere with the inventions of either of the other gentlemen who have applied to your honorable body for an exclusive right of navigating by means of steam." The petitioner avers that he had "made an exact draught of the different parts of his machine, which, with an explanation thereof, he is ready to exhibit." The prayer of the petition was unsuccessful; but

these draughts should be among the papers of the late Colonel Stevens, and at this day would be curious.

Mr. Stevens, meanwhile, never renounced his experiments nor despaired of success, and in 1804 he actually constructed a propeller (a small open boat, worked by steam), with such decided success that he was encouraged to go on and build the Phenix, steamboat, on his own plan and model, and had her ready almost contemporaneously with, but a little after, the first steamboat of Fulton, the *Clermont.* The *Clermont* entitled Mr. Fulton and Chancellor Livingston, who was co-operating with Fulton, to the benefit of the law, which had been revived by the State of New York, granting a monopoly of the waters of the State, and thus Mr. Stevens' steamboat was excluded from those waters. On the Delaware, however, and on the Connecticut he placed boats; and his eminent son, Robert L. Stevens, having embraced his father's views, was now at work with him to improve the known, and invent new resources for accelerated steam conveyance.

In 1812, just before the commencement of the war with England, and when this State was first addressing itself to the thought of connecting the waters of the lakes with those of the ocean by the Hudson, a thought, very .apidly matured, in the sequel, by the delays and now incredible cost in transporting troops, artillery and munitions during the war from the seaboard to the lakes, Colonel Stevens put forth the pamphlet here reproduced, urging that railroads and steam-carriages should be preferred to canals and canal boats.

At that day not a locomotive existed in the world, and the only railroads were those few and short tram-roads, as they were called in England, connecting for the most part coal mines with canals, or other water transportation, and upon which carriages with the ordinary wheels turning upon their axletrees were drawn by horses. The carriages were prevented from running off sideways by a flange rising some inches above the outer edge of the flat rail. In this state of knowledge and experience of railroads it was that, in 1812, Colonel Stevens made public, in the following pamphlet, his extraordinary and most sagacious views and accurate calculations respecting, not only the feasibility of applying steam to locomotion on land, but

the precise mode of such application, its cost, and its almost illimitable advantages. It seems all but impossible to realize the fact, when carefully reading his description of the railway, of the locomotive—of its wheels made fast to the axle, and revolving not *on* but *with* it, and held by flanges on the inner periphery, from flying off at a tangent; of a whole train, or "suit," as he calls it, of railway carriages, "all firmly attached to each other, and pursuing the same direction;" and of the possible speed they might attain of forty or fifty miles an hour, but that probably "it would in practice be found convenient not to exceed twenty or thirty miles an hour;" it seems, I repeat, almost impossible to realize the fact that, at that day no locomotive existed except in the creative and ingenious mind of the writer; and that no railroad, such as he needed for his unrevealed plan, had ever been laid down.

If he had seen then, what he lived to see afterwards, and from the handiwork and genius mainly of his son Robert on the Camden and Amboy Railroad, the spectacle, ever impressive, however frequently witnessed, of long trains of cars sweeping on with the rapidity of the pigeon's flight, he could not have described with more absolute accuracy all the details of such train, such a road, and such a locomotive, than is done in the prophetic pamphlet of 1812.

He was treated as a "visionary projector." Time has vindicated his claim to the character of a far-seeing, accurate and skilful practical experimentalist and inventor; and who can estimate, if at that day, acting upon the well-considered suggestion of President Madison, "of the signal advantages to be derived to the United States from a general system of internal communication and conveyance," Congress had entertained Colonel Stevens' proposals, and after verifying, by actual experiment upon a small scale, the accuracy of his plan, had organized such a "general system of internal communication and conveyance;" who can begin to estimate the inappreciable benefits that would have resulted therefrom to the comfort, the wealth, the power, and above all, to the absolutely impregnable union of our great republic and all its component parts?

All this, too, Colonel Stevens embraced in his views; for he was a statesman as well as an experimental philosopher, and

whosoever shall attentively read this pamphlet will perceive that the political, financial, commercial and military aspects of this great question were all present to Colonel Stevens' mind; and he felt that he was fulfilling a patriotic duty when he placed at the disposal of his native country these fruits of his genius.

The offering was not accepted. The thinker was ahead of his age; but it is grateful to know that he lived to see his projects carried out, though not by the Government, and that, before he finally in 1838 closed his eyes in death, at the great age of 89, he could justly feel assured that the name of Stevens, in his own person and that of his sons, was imperishably enrolled among those which a grateful country will cherish.

I will detain the reader no longer from the pamphlet.

CHARLES KING.

COLUMBIA COLLEGE, New York, May, 1852.

INTRODUCTION.

The following documents on a subject calculated, I should suppose, to attract public attention, are committed to the press from an estimation of their importance, and from a conviction of the practicability of the proposed improvement. On a subject of such deep interest to the community at large, I presume no apology will be necessary for the liberty I now take of laying before the public private communications.

Had the subject matter of this publication been exhibited to public view in the shape of an entire and connected essay, written expressly for the purpose, numerous repetitions and inaccuracies, both in style and matter, would not have occurred. But, I am inclined to believe, that the desultory manner in which it is now handled, and the unavoidable repetitions necessarily resulting therefrom, will render it more generally impressive.

Although my proposal has failed to gain the approbation of the Commissioners for the Improvement of Inland Navigation in the State of New York, yet I feel by no means discouraged respecting the final success of the project. The very objections their committee have brought forward serve only to

increase, if possible, my confidence in the superiority of the proposed railways to canals.

So many and so important are the advantages which these States would derive from the general adoption of the proposed railways that they ought, in my humble opinion, to become an object of primary attention to the National Government. The insignificant sum of two or three thousand dollars would be adequate to give the project a fair trial. On the success of this experiment a plan should be digested, "a general system of internal communication and conveyance" adopted, and the necessary surveys made for the extension of these ways in all directions, so as to embrace and unite every section of this extensive empire. It might then, indeed, be truly said, that these States would constitute one family, intimately connected, and held together in indissoluble bonds of union.

Should the National Government be induced to make an appropriation to the amount above stated, an experiment could soon be made, either in the vicinity of this city or at Washington, as may be deemed most expedient.

But the attention of the general government is urged more imperatively to this object, from the consideration of its great national importance in a fiscal point of view. If any reliance can be placed on the calculations I have made, the revenue which this mode of transportation, when brought into general use, would be capable of producing, would far exceed the aggregate amount of duties on foreign importations. However extravagant this position may at first sight appear, I contend it is capable of the strictest demonstration. It is an indisputable fact that the aggregate amount of internal commerce is vastly greater than that of external commerce.

But one-half of the latter, viz., exports, are by the constitution exempted from the payment of duties; the other half, foreign imports only, are subject to the payment of duties.

The far greater part of domestic commerce consists of bulky articles, many of which *now* pay 50 per cent. on transportation to market. By the introduction of the proposed railways, nine-tenths at least of this enormous tax would in many instances be saved, and the expense of transportation reduced from 50 to 5 per cent. A toll of 5 per cent. would

raise it to 10 per cent. But still the farmer, remotely situated, would save four-fifths of his present expense in the transportation of his produce to market. An average toll, then, of 5 per cent. would constitute a very moderate impost. But the product of such an impost would, at no distant period, be immense. That it would far exceed any amount which could possibly be derived from duties on foreign imports, cannot admit of a doubt.

At a period like the present, when the ordinary sources of revenue no longer continue to pour into the treasury of the United States their tributary streams, and when, too, we are called upon to make "arrangements and exertions for the general security," at such a period, the merits of a system promising, not merely to facilitate most astonishingly "internal communication and conveyance," but to furnish new and abundant sources of revenue, ought surely to command the attention of the general government, and cannot fail to "be seen in the strongest lights."

The extension and completion of the main arteries of such a system of communication would by no means be a work of time. It would be exempted totally from the difficulties, embarrassments, casualties, interruptions, and delays incident to the formation of canals. Requiring no supply of water, no precision and accuracy in leveling, the work could be commenced and carried on in various detached parts; its progress would be rapid, and its completion could be ascertained with certainty. Innumerable ramifications would, from time to time, be extended in every direction. Thus would the sources of private and public wealth, going hand in hand, increase with a rapidity beyond all parallel. For every shilling contributed towards the revenue, a dollar at least would be put into the hands of individuals.

But there remains another important point of view, in which this improvement demands the attention of the general government. The celerity of communication it would afford with the distant sections of our wide extended empire, is a consideration of the utmost moment. To the rapidity of the motion of a steam carriage on these railways no definite limit can be set. The flying proas, as they are called by voyagers,

belonging to the natives of the islands in the Pacific ocean, are said at times to sail more than twenty miles an hour. Since the resistance of the water to the progress of a vessel increases as the square of her velocity, it is obvious that the power required to propel her, must also be increased in the same ratio. Not so with a steam carriage. As it moves in a fluid 800 times more rare than water, the resistance will be proportionably disminished. Indeed, the principal resistance to its motion arises from friction, which does not even increase in a direct ratio with the velocity of the carriage. If, then, a proa can be driven by the wind (the propulsive power of which is constantly diminishing, as the velocity of the proa increases) through so dense a fluid as water, at the rate of twenty miles an hour, I can see nothing to hinder a steam carriage from moving on these ways with a velocity of 100 miles an hour.*

I will now just observe, that should it be considered an object of sufficient importance, sails might be used whenever the wind was favorable. Van Bram gives a curious account of the peasantry in the country round Pekin, availing themselves of sails, when the wind favors them for propelling the whellbarrows in which their products are carried to markets.

In a military point of view, the advantages resulting from the establishment of these railways and steam carriages would be incalculable. It would at once render our frontiers on every side invulnerable. Armies could be conveyed in twenty-four hours a greater distance than it would now take them weeks, or perhaps months, to march.

Thus, then, this improvement would afford us prompt and effectual means, not only of guarding against the attacks of foreign enemies, but of expeditiously quelling internal commotions, and thus securing and preserving forever domestic tranquillity.

Whatever constitutional doubts may be entertained respecting the power of Congress to cut and form canals, there can be none about the power to lay out and make roads.

* This astonishing velocity is considered here as merely possible; it is probable that it may not in practice be convenient to exceed 20 or 30 miles per hour. Actual experiments, however, can alone determine this matter, and I should not be surprised at seeing steam carriages propelled at the rate of 40 or 50 miles an hour.

I shall now close this topic with an extract of a message from President Madison to the Senate and House of Representatives of the United States:

"The utility of canal navigation is universally admitted; and it is not less certain, that scarcely any country offers more extensive opportunities for that branch of improvements than the United States; and none, perhaps, inducements equally persuasive, to make the most of them. The particular undertaking contemplated by the State of New York, which marks an honorable spirit of enterprise, and comprises objects of national, as well as more limited importance, will recall the attention of Congress to the signal advantages to be derived to the United States from a general system of internal communication and conveyance; and suggest to their consideration whatever steps may be proper on their part towards its introduction and accomplishment. As some of those advantages have an intimate connection with arrangements and exertions for the general security, it is at a period calling for these, that the merits of such a system will be seen in the strongest lights.

"JAMES MADISON.

"Washington, Dec. 2, 1811."

From local circumstances, these railways are calculated to become pre-eminently beneficial to the Southern States. The great predominance of sand, and the deficiency of gravel or stone, precludes the practicability of making good turnpike roads; but the level surface, and great abundance of pine timber throughout this district of country, would not only render the construction of these railways very cheap, but peculiarly advantageous. By preserving nearly a horizontal level, the power requisite for the transportation of heavy bodies would be reduced astonishingly. The cheapness of fuel would reduce, too, the expense of supporting this power to almost nothing. Articles would be transported one hundred miles on these ways at less expense than they could now be carried one mile on a deep, sandy road. This projected improvement is surely then an object worthy of the most serious attention of the inhabitants of the Southern States. It would at once more than double the value of their products. It appears to me calcu-

culated to hold out the most flattering prospects of gain to such enterprising individuals or companies as might be induced to embark a capital in this object.

But, I consider it in every point of view so exclusively an object of national concern, that I shall give no encouragement to private speculations, until it is ascertained that Congress will not be disposed to pay any attention to it.

Should it, however, be destined to remain unnoticed by the general government, I must confess I should feel much regret, not so much from personal, as from public considerations. I am anxious and ambitious that my native country should have the honor of being the first to introduce an improvement of such immense importance to society at large, and should feel the utmost reluctance at being compelled to resort to foreigners in the first instance. As no doubt exists in my mind, but that the value of the improvements would be duly appreciated and carried into immediate effect by transatlantic governments, I have been the more urgent in pressing the subject on the attention of Congress. Whatever, then, may be its fate should this appeal be considered obtrusive and unimportant or from whatever other cause or motive should it be suffered to remain unheeded, I still have the consolation of having performed what I conceive to be a public duty.

JOHN STEVENS.

NEW YORK, May 15, 1812.

DOCUMENTS, ETC.

No. 1.

Copy of a letter addressed to De Witt Clinton, Esq.

NEW YORK, February 24, 1812.

THE HON. DE WITT CLINTON, ESQ.:

Sir:

I inclose a memoir addressed to the Commissioners for Exploring an Inland Navigation, etc.

The more I reflect on the plan I have proposed, the more thorough is my conviction, not merely of its practicability but that it must eventually supersede every other mode of conveyance

ance, where the nature of the country will admit of its introduction. Under such impressions I consider myself impelled by duty to urge its adoption by the Commissioners. An experiment sufficiently extensive, to ascertain unquestionably its real merits or demerits, could be tried at the expense of two or three thousand dollars.

With sentiments of respect, I am, Sir, your ob't serv't,

JOHN STEVENS.

No. 2.

Copy of Mr. De Witt Clinton's answer to the above.

ALBANY, March 2, 1812.

Dear Sir:

I have received your interesting communication addressed to the Commissioners of Inland Navigation, etc., and shall lay it before the Board at their first meeting.

With my best compliments, I am yours respectfully,

DE WITT CLINTON.

John Stevens, Esq.

No. 3.

Copy of a memoir addressed to the Commissioners.

To the Hon. the Commissioners for Exploring the Route of an Inland Navigation, etc.

The report of the Commissioners appointed by the Legislature of this State, to explore the route of an inland navigation from Hudson River to Lake Ontario and Lake Erie, contains a luminous exposition of the vast importance of facilitating the intercourse between the western country and the tide-waters of Hudson's River.

The plan suggested of bringing the waters of Lake Erie in a canal, on an inclined plane of three hundred miles in length, to communicate with Hudson's River, is unparalleled for the boldness of its conception, and the grandeur of its object. But the magnitude of such an undertaking must necessarily protract the completion of it to a very distant day, and will have a powerful tendency to make many hesitate respecting

the expediency of incurring so heavy an expenditure upon an object presenting so distant a prospect of remuneration.

Still, however, I must concur most heartily with the Commissioners, when they observe "that no supposable expense can bear an undue proportion to the value of the work. Thus were it (by giving a loose to fancy) extended to fifty millions of dollars, even that enormous sum does not exceed half the value of what, in all human probability and at no distant period, will annually be carried along the canal. The more proper question perhaps is, in what time it can be effected?"

But, independently of the great consumption of time and money incident to so vast an undertaking, there are other circumstances which require serious consideration.

The contemplated route of this canal lies nearly in an east course from Lake Erie to Albany, and in a high northern latitude, where everything remains locked up by frost for almost five months during the winter season. Whereas, the southern border of Lake Erie is in a latitude one and a half degrees lower, from whence easy communications may be formed with the head waters of the Ohio and Susquehanna, and but little interrupted by ice.

These routes, it must be confessed, are very circuitous, and the navigation of the natural rivers in their present state, very troublesome and tedious. From the nearest point on Lake Erie, to tide-water on the Delaware, at Philadelphia, on the Chesapeake, at Havre de Grace, or Baltimore, in a straight line, is but a few miles farther than to Albany. But to form a practicable navigation to either of those places by means of canals, would make a difference of at least an hundred miles in favor of Albany. But as it respects the nature of the ground through which these canals must pass, there is no comparison; so great and so numerous are the elevations, that the route to Albany is comparatively level. When, in addition to these advantageous circumstances, we take into consideration the decided superiority of the City of New York, in a commercial point of view, it will not be practicable to divert into another channel the current of trade, when once fairly established, from the interior to this city. When, therefore, the immense magnitude of this internal commerce is duly appreciated, every in-

vidual inhabitant of this State, but more especially of this city, ought to feel himself interested in the accomplishment of so grand an object.

From the above view of the subject, it appears that there are two considerations of primary importance to be attended to:— first, that this communication with the western country be completed with all possible dispatch; and next, that if practicable, such a mode of effecting the purpose be adopted, as that the travel shall at no time be interrupted.

Without further preface, I will now proceed to propose a plan, which, I flatter myself, embraces both these important objects. Let a railway of timber be formed, by the nearest practicable route between Lake Erie and Albany. The angle of elevation in no part to exceed one degree, or such an elevation, whatever it may be, as will admit of wheel-carriages to remain stationary when no power is exerted to impel them forward. This railway, throughout its course, to be supported on pillars raised from three to five or six feet from the surface of the ground. The carriage wheels of cast iron, the rims flat, with projecting flanges, to fit on the surface of the railways. The moving power to be a steam engine, nearly similar in construction to that on board the *Juliana*, a ferry-boat plying between this city and Hoboken.*

It would be altogether unnecessary to go into a detailed description of the mode of adapting and applying the machin-

* The steam ferry-boat *Juliana* here referred to was built by Col. Stevens, in 1811. She was an undecked, open boat, 62 feet in length, and only 12 feet in breadth, drawing from two and one-half to three feet water. The engine in her was of the model patented by Col. Stevens, having a cylinder of fourteen inches diameter, and two and a half feet stroke; with copper boilers, cylindrical, with flues. The steam was used expansively, cut off in the main valves, as is *now* done in the most approved engines. The *Juliana* attained a speed of seven miles an hour. Mr. Fulton, having an interest in the Jersey City Ferry, objected to the right of Col. Stevens to run the *Juliana* as a ferry-boat between Hoboken and New York City, as infringing his monopoly from the State of New York, and the *Juliana* was driven off.

She afterwards plied on the Connecticut River between Middletown and Hartford, being the first boat to navigate the Sound, *although undecked*, as Col. Stevens' boat *Phenix* was the first, in 1808, to navigate the ocean, between Sandy Hook and the Delaware.

ery of a steam-engine to the purpose of propelling carriages placed on railways. It is sufficient to say, that I feel the fullest confidence in being able to convince an experienced and skilful engineer of the entire practicability of the plan.

I shall now attempt to explain the many and important advantages resulting from carrying this plan into effect.

In the first place, as to expense. On the most exaggerated scale of calculation, the expense of such a railway would not exceed that of an ordinary turnpike road with a good coat of gravel on it.

Second. The far greater part of the work can be performed by common laborers, and as no accuracy of leveling would be required, it may be commenced and carried on in as many different places as may be found expedient. It might, therefore, be accomplished with ease in one or two seasons.

Third. From its elevation above the surface of the ground, the timber of which the railway is framed will be little subject to decay; and from this elevation, too, the travel on it can never be interrupted, as it will be raised above the ordinary level of the deepest snows.

Fourth. These railways, from the nature of their construction, will be free from the numerous casualties to which canals are liable.

Fifth. The expense of transportation would be much less than on a canal of the best construction.

To prove this, a summary calculation will be necessary.

The Commissioners inform us (under the authority of Mr. Latrobe) that "by the aid of a railway, one horse would transport eight tons, supposing the angle of ascent not to exceed one degree."

In *Nicholson's Journal* is an account of one horse transporting for several miles on a railway the enormous weight of fifty tons.

A small steam-engine, then, of ten inches diameter, worked with steam, the elastic power of which was fifty pounds to the circular inch, would possess a power equal to five thousand pounds on the whole area of the piston, moving with a velocity of three feet in a second. This exceeds the power of twenty horses; but one horse, as above stated, can transport on a rail-

way eight tons, and twenty horses would, at the same rate, transport 160 tons.

But after making every possible reduction for exaggeration, we may fairly state, in round numbers, that a steam-engine, with a cylinder of ten inches diameter, worked on the above principles, would be capable of transporting on a railway 100 tons at the rate of four miles per hour. It must be recollected that Mr. Latrobe's estimate, above stated, is founded on an ascent of one degree. Now, this would give an elevation of ninety-two feet and upwards for every mile. The whole difference of elevation estimated by the Commissioners, between the tide-water at Albany and the surface of Lake Erie, is 525 feet.

To gain this ascent, therefore, would require somewhat less than six miles. This bears so small a proportion to the whole distance, that it would be but in a trifling degree erroneous to consider the whole distance as one level. This would much more than compensate for an increase of the rate of velocity in the steam-carriage, from two and a half miles to four miles an hour, especially when we advert to the well-authenticated experiment above stated, viz., that a horse is capable of transporting more than fifty tons on a level railway, whereas the above is founded on an estimate of only five tons to each horse.

We will now proceed to estimate the expense per ton of this mode of transportation.

The steam-engine of the above-mentioned size would require about a cord of wood to keep it constantly going for the whole twenty-four hours ; but to silence all cavil, we will state the consumption of wood at three cords a day. Wood, at an average throughout the entire distance, may be procured for one dollar a cord, but we will estimate it at two dollars a cord.

To attend the fire, and perform any other services that may be required, we will allow four men, at one dollar each per day, is four dollars ; which, added to the cost of three cords of wood, would make ten dollars a day. The whole distance, then, of 280 miles, from Lake Erie to Albany, would be traveled in three days. Say the back load would average only one-third of a full freight, there would then remain five days at ten dollars a day, amounting to fifty dollars, for the expense of

transporting one hundred tons of produce a distance of 280 miles, which is at the rate of fifty cents per ton. But the Commissioners have estimated the expense of transportation through the contemplated canal, from Lake Erie to Hudson's River, at three dollars per ton.

In the above calculation, interest on the capital expended, wear and tear and repair of machinery, carriages, railways, etc., and no doubt many other incidental charges, are not included. But were we even to double the rate of transportation, raising it from fifty cents to one dollar per ton, still it would amount to only one-third of what the Commissioners have stated, as above. But if the construction of railways would require only about one-fourth of the capital estimated for a canal, and the transportation thereon could be afforded at one dollar per ton, instead of three dollars, it is easy to see what an immense revenue the Stafe might derive from toil, and still permit transportation to be performed for much less than it could be done by a canal.

But here I expect to be encountered at the very threshold —to be stigmatized as a visionary projector. Have not, it will be said, steam-engines and railways been long in use in England? And should it be practicable to apply them to such immense advantage in the improvement of transportation, would it not have been done in that country long ago? To this *argumentum ad hominem*, thanks to the enterprise and active genius of our citizens, we are now furnished with ready and conclusive answers. Mr. Latrobe, in a memoir published in the third volume of the "Transactions of the American Philosophical Society," animadverting on the projects "for propelling boats by steam-engines," uses these remarkable expressions: "A sort of mania began to prevail, which indeed has not yet entirely subsided." It is surely unnecessary to say that, in despite of the formidable objections (no less than six) he has urged, "from which," as he tells us, "no particular mode of application can be free," in despite of these anathemas, the project, as we all with pleasure can testify, has completely succeeded. Another gentleman, in the *American Medical and Philosophical Register* for April, 1811, has given a demonstration to prove that a small obstacle would be sufficient to stop a car-

riage impelled by a steam-engine. That on roads perfectly hard and smooth, it could not ascend an inclined plane of seven or eight degrees; and concludes by saying that "in whatever point of view we place this subject, we shall be more and more convinced of its futility." He, however, in another place, expresses himself as follows:

"If roads were perfectly hard, smooth and level, such an engine would probably have the advantage over common carriages, because a small power continually exerted would give a degree of velocity that could not be supported by horses." This admission is amply sufficient to defend the plan now proposed against the force of his demonstration, and renders it unnecessary to go into any investigation to point out its defects. If, then, notwithstanding the host of objections "from which no particular plan can be free," the steam-engine has been successfully applied to propelling boats, we surely need not despair of applying it with success, also to propelling carriages. But, surely, the mere novelty and magnitude of the proposed improvement ought not to startle us. We are too apt to look up with reverential awe to what has usually been called the mother country, for every improvement in the arts, without considering how recent has been the introduction and establishment of these arts in that very country.

"It is about a century ago that the first crude attempts to apply the power of steam to useful purposes were made; and it is, as it were, but yesterday that the Duke of Bridgewater first introduced canals, which have since been so astonishingly multiplied in that country. And as to railways, they are of a much more recent date, and are at present very limited in their use and application. A project, therefore, promising such vast improvement in the transportation of commodities to and from the interior of our country, if not stamped with absurdity on the very face of it, surely merits the most serious consideration, and on this occasion I have every reason to felicitate myself on my good fortune.

"When I reflect on the high standing in society, and enlightened patriotism of the gentlemen who are, in the first instance, to pass judgment on the plan I have proposed, I feel perfectly

satisfied that its real merits, whatever they may be, will be dul y appreciated.

"It may be objected, that, although the elevation of the rai l- ways may secure them, in a great measure, from decay, yet th e constant transit of the wheels over them will very soon wea r them out, in like manner as we see happens to the plank o n bridges. But the cases are by no means similar. As the plan k on bridges are laid crossways, the warping of the plank, and th e enlargement of the cracks or seams between each, causes in - equalities in the surface; this produces more or less jolting in the motion of the wheels of carriages passing over. But wh at tends still more to wear away the plank, are the heads of th e nails in the tire of the wheels, and also the nails and calks in the horseshoes; whereas the surfaces of both the railways, an d the rims of the carriage wheels, are made, in the first instanc e, perfectly smooth, and free from all inequalities of surface; an d, as the rims of the wheels will always continue so, the railwa ys can never be affected by anything except mere pressure. I should presume, therefore, that they will be but little subject to wear. But wherever this wear takes place, they can be re- newed again at a trifling expense. But should, contrary to expectation, experience prove these railways to be so subj ect to wear, as that the frequency of their renewal becomes in- convenient and expensive, recourse could be had at any ti me to cast or plated iron railways, which, without any further tr u- ble and expense, could be fastened on the top of the wood en railways.

"I would beg leave to suggest, that an experiment, by wh ich the real value of the plan now proposed might be complet ely and satisfactorily ascertained, could be made for a few thousa nd dollars.

"As the power of the engine is expended principally in overcoming friction, which is increased in but a small degree by an increase of velocity, and may be removed almost entirely by using friction wheels, a carriage may be made, by a small increase of power, to acquire a velocity far greater than could be given by the fleetest horses; and as, too, the railways must be incomparably better than the best turnpike road could possibly be made, I am by no means prepared to say what

limits may be set to the rapidity with which a carriage may be driven on these ways.

"JOHN STEVENS.

"New York, Feb. 24, 1812."

(*To be continued.*)

THE CONSERVATION OF ENERGY.*

To the Editor of ENGINEERING:

SIR:—While I have no exception to make to your general statement as to the relativity of all human knowledge, I feel as if a few words of explanation might be useful to prevent what you have said from being misused by those who are making a business of misleading the public.

While it may be true that our confidence that two and two cannot make five is of a higher order than our confidence that the law of gravitation is universal, and the conservation of energy is absolute, yet is not this a difference of degree, the result of our progressive evolution, and may not the time be coming when one will be as near to absolute knowledge as the other?

It is stated on good authority by Buckle that some native Africans are not able to see that two and two make four; but that when sheep are bought from them for two quids of tobacco each, it will not satisfy them to give them four quids for two sheep, but each animal must be separately exchanged for two quids.

Is not our practical realization of the relation of numbers the result of ancestral experience, and may we not hope that our descendants may have an equally intuitive perception as to the relation of the various forms of energy? Without waiting, however, for this as a practical question, is not our experience on the conservation of energy already sufficiently extended to warrant us in treating it as a *practical* axiom on which we may safely base our actions in all practical questions?

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* *Engineering*, London, May 17, 1895.

Clerk Maxwell's name properly gives weight to anything he has said, even if it is of the nature of a dream about demons; but if even Homer sometimes nods, may not a modern physicist "drop off" when he lays aside the conception of material substances, and turns his mind upon what supernatural agencies might accomplish in a domain of dematerialized matter?

Allow me in this connection to present to you a letter which I have just received from Professor J. Burkitt Webb, of our faculty, in response to an inquiry as to his views concerning Maxwell's demon engine.

Very truly yours,

HENRY MORTON.

APRIL 29, 1895.

PRESIDENT MORTON:—The reference to Maxwell's "familiars" in the article in *Engineering*, which refers to your article in *Cassier's Magazine*, calls to mind the impression produced when I first read Maxwell's "Theory of Heat." It was delightful reading until I came to his well-known demoniacal suggestion on page 328, and this sounded like a painful discord.

In the first place, there seemed to be no force in it, because most people would agree that the Creator could interfere with His own laws if He wanted to. Thus we may hold that the quantity of matter in the universe is constant, and yet, if it was created, the Creator might certainly be able to add to, or subtract from, it. Now Maxwell's demons, notwithstanding his claim that they are "essentially finite," are supposed to have the attributes of the Creator, inasmuch as they must be spirits of infinite, or very superior, intelligence, able at once to discern what particles should be, and what should not be, let through the partition, and having no material bodies. Incidentally, it seems quite appropriate that they should be popularly called demons, in accordance with the supposition that such beings are experts in matters involving the manipulation of high temperatures.

This suggestion of Maxwell struck me otherwise as somewhat crude, like the machines often proposed by inventors, which could never be constructed, and would not operate if

they could be. Thus the partition, separating the two spaces and in which the doors are to be located, must be a material partition, for we know of, and consequently can assume, no other; and doors in such a partition, being also material, could not be operated without energy. The operation of the doors without loss of energy is, therefore, inconceivable, and the same objection holds against material bodies for the demons. This being the case, it is unnecessary to go farther in showing that the proposed plan for elevating the temperature of a gas is not in accordance with natural laws.

But there is another quite interesting view of the case, which places the device, for thus accumulating heat and using it to run a heat-engine, far below the plane of a real "Yankee" invention, for had Maxwell his demons organized and his engine ready to start, he would need only to change his instructions somewhat to make the thing a greater success than he imagined. Thus, in giving orders to the demons, it would be much better to tell them to let all molecules through the partition toward the engine, but to let none back, so that nothing would be needed for the production of mechanical power but a compressed-air engine and reservoir for the patent *demoniacal surface* or partition. That is to say, if the reservoir were made so that demons could let molecules into, and not out of it, or if the walls were filled with minute, frictionless, immaterial, or demoniacal check-valves, which would let particles in and not out, then we could automatically keep the pressure up in such a reservoir, without caring to raise its temperature, while we ran an air engine from it.

This, as you see, is a legitimate child, of what seems to me the first absurdity, and would at once make perpetual motion (that is, automatic power supply) theoretically impossible.

There is, however, a curious side issue which might be developed in case the demon engine above suggested could be put into operation. For the demons to let all molecules through, and none back, would be as if a farmer, desiring to collect all his unwilling cattle in a pen, might set some one to driving them rapidly about the field, so that when one came accidentally toward the gate of the farmer, he could open it and let that one through, taking care to do so only when none on the inside

uld come out. Of course, after a while the smarter cattle, at st, would begin to steer clear of the gate, and this might lead to regard with favor Tyndall's unorthodox suggestion that : germs of everything, intelligence included, may exist in the ginal atom, and to conclude that after a little the molecules uld, perhaps after a consultation between their component ms, see the point and avoid the demons and their doors, in : fear that some additional and unauthorized service was to gotten out of them, even if they did not get the hint of it m those molecules which returned to them fagged out with ir efforts in running the engine.

Respectfully,

J. BURKITT WEBB.

P. S.—A copy of my vice-presidential address before Sec- n D of the American Association for the Advancement of ence in 1885 accompanies this. On page 4 you will find an idental protest against Maxwell's theory.

J. B. W.

COMMENCEMENT WEEK.

The baccalaureate sermon was preached by Rev. William R. Jenvey at St. Paul's Church, Hoboken, on Sunday, June 16.

On Monday, at 3 o'clock, the class of '95 made a formal presentation in the electrical laboratory of a 30 H. P. Payne high-speed engine, which had been purchased and set up in the electrical laboratory as a parting gift by the class to the Institute. An interesting program had been arranged, including an exhibition of electrical experiments, conducted by Mr. A. F. Ganz, which was witnessed by many of the invited friends of the class.

The Electrocution of Calculus introduced a novel and highly creditable method of celebrating the subjugation of this sore disturber of the peace of sophomores. At 8 P. M., on the 17th, the class of '97 and members of the other classes formed in procession at the Institute, and, preceded by the Castle Point Drum and Fife Corps, marched to the Quartette Club Hall. The room was already well filled, among those present being the president and most of the members of the faculty.

A three-act play, written by Mr. William D. Ennis, '97, in which the capture, trial and electrocution of a living impersonation of "the fiend" were the prominent incidents, was performed by members of the class. Laughter and applause greeted the frequent allusions by dress, action or speech, to occurrences or to individual peculiarities, which had attracted the notice of the students, and which had been introduced by the author in a most amusing manner, in good taste, and entirely free from offense to the persons to whom attention was directed.

It was an entertainment which would have been thoroughly enjoyed by the lady friends of the students and of the Institute, who, however, had unfortunately not been invited to this first trial of an innovation. The reception of this play and the success achieved, will doubtless encourage future classes to

welcome on such occasions the ladies, who are generally well posted on current Institute events.

At the conclusion of the play, the undergraduates were invited to a supper provided in the basement of the hall by President Morton, whose hospitality added greatly to the thorough enjoyment of the occasion.

At 4 o'clock, on Tuesday, Rho Chapter of Delta Tau Delta Society gave an afternoon tea to the members of the faculty and their wives, and to other friends.

At 8 o'clock, the same evening, the farewell dinner of the graduating class was served at Hotel Marlborough, Broadway and 36th Street, New York.

On Wednesday, President and Mrs. Morton tendered a reception to the faculty and the members of the graduating class, from 4 to 7.

The annual meeting of the Alumni Association was held at 8 o'clock the same evening.

The Commencement Exercises, held on Thursday evening, at the Hoboken Theatre, were opened shortly after 8 o'clock, with prayer by Rev. William R. Jenvey.

President Morton, in a short address, referred to the encouragement the friends of the Institute, as well as the undergraduates, may derive from the experience time has brought us of the degree of success achieved by Stevens men. Of about five hundred graduates, more than one hundred are occupying positions of responsibility and power. Ten of them are presidents or vice-presidents of manufacturing or engineering concerns; seven are superintendents of motive power on railroads, some of which are the most extensive in this country; and thirty are professors in colleges. Of the class now to graduate, a considerable number have business openings already in view. He complimented the class on its creditable record, and spoke of the moral tone of the student body as excellent. He then introduced Mr. C. Austin Greenidge, who delivered the salutatory.

SALUTATORY ADDRESS.

"Mr. President, Gentlemen of the Faculty, Trustees, Fellow-Student and Friends:

"You are assembled here this evening to witness the closing hour of our college career. On behalf of the Class of Ninety-five, I take pleasure in bidding you a hearty welcome to these Commencement Exercises and thank you for the honor you confer by your presence.

"It is not without a feeling of sadness, however, that I perform this otherwise pleasant duty, for this occasion marks the severance of our connection as students with the Institute which during the short four years of our course has become so dear to our hearts. We all feel, as naturally we should, jubilant over the arrival of this auspicious hour; but there is not one of our number who does not, for some reason, regret that our college days are at an end. There have been moments when student life was irksome and we thought how much better off we would be out in the world and on the highroad to success; but it will not be long before we realize that the tasks we have set for us are, after all, easier than those we may be compelled to set for ourselves.

"Many of you who are present have watched with hopeful eyes our progress at Stevens, and know well that this stage in life's journey has not been reached without great mental effort and frequent burning of the midnight oil. You have seen our countenances clouded with looks of anxiety, as each term approached its end. You have also seen those looks disappear and give place to smiles of satisfaction as each examination was successfully passed, and you are no doubt in a congratulatory mood this evening when you see us hopefully awaiting the presentation of our diplomas. These diplomas, which four years ago appeared to us in the form of a vision, are to-night a reality, having cast off their aërial form for one more tangible.

"Our college career may in a way be compared to the development of the worm into the chrysalis and finally into the butterfly. We have passed from the worm state of the Freshman to the chrysalis state of the Senior. To-night we break the now thin shell of college life, and, like the butterflies, we are about to go forth to flit among the flowers in life's garden, therefrom to gather our share of the nectar of success.

"The profession we have chosen is a noble one, having for its sole object the discovery and utilization of the truth; and

what can develop higher qualities of mind, nobler characteristics of nature, than the love and pursuit of truth? In following our choice thus far, we have been fortunate in having our course guided by a kind and considerate Faculty, headed by one who, while a strict disciplinarian, was at the same time a courteous gentleman and a true friend.

"For twenty-two years our Alma Mater has been sending forth her coterie of laborers to the field of engineering. Starting in 1873 with one graduate and keeping steadily onward till this evening, the twenty-third and largest class of forty-five members presents itself to receive the final words of encouragement and the parting gift.

"In this happy hour we must not forget those who started with us, having the same hopes and fears as we ourselves, for only fifty per cent. of our original number remain. Some have seen fit to enter other fields of labor, while others, through failing health, have been obliged to seek an easier task or follow in the rear; but we are especially fortunate in that we have not been visited by the grim hand of death, and have thus only to regret the departure and not the loss of our former companions."

The address to the graduating class was made by the Hon. John M. Gregory, LL.D., of Washington, D. C., who spoke as follows:

For many years it has been my duty to deliver addresses to the graduates of educational institutions; to give them cheer as they leave their college homes, to fight the battle of life in the outer world.

As a representative of that great outer world, which waits to welcome you, it is my serious duty to bid and entreat you to come forth to our side, to stand shoulder to shoulder with us, as trained helpers in our work, as fresh reinforcements on our great battle-field, where so much is expected and demanded of each individual, as sympathetic comrades in the great life march from the cradle to the coffin, from our mothers' arms to the cold embrace of mother earth.

It is but a barren formality to welcome you to the great opportunities which the century in which we live opens to you.

You too, with us, are rightful heirs of the ages. The splendid progress and achievements of this nineteenth century are not ours more than yours. They are growths from the seeding of the past generations, and they are yours as well as ours, to enjoy, use, and improve, and so to pass on to the coming generations of our race.

But, out of the years of toil and experience, let me mark for you some of the grander features of that stage on which you are about to step. It must already have caught your eye that the field of human life and labor is not all one dead-level, one uniform plane of action and endeavor. I refer not to the various stages of fortune which divide the ignorant from the intelligent, the poor from the rich, or the bad from the good; but to those great natural planes of human life to which the physical, psychic, and spiritual nature of a man introduces him.

Man emerges at birth on a plane of life, whose great scientific law is the "*Struggle for Existence.*" This is the plane of pure and simple *Selfism* or *Egoism.* In its lower and degraded form it is base selfishness; in its higher and more refined state, it is a proud individualism.

On this plane, man's activities develop into the arts and industries, and wealth in all its forms appears.

I need not urge you to be active in this plane. All around you will impel you to this. The needs and ambitions of life will give you inspiration. I will not insult your common sense by defaming or belittling the rightfulness or importance of this mighty and instinctive struggle for life and its comforts; and you do not need that I shall warn you against perverting this struggle to the miser's toil for gold, or enlarging it till it absorbs and corrupts the whole powers of life.

The education you young men have no one can take from you. Be kindly and helpful to all, be honest and true in your work, and lend your skill and science freely to the multitudes who have lacked your opportunities.

The splendor of man's mighty victories over nature and its forces has taken nearly all the savagery and meanness from this struggle for existence, and turned it into a kingly triumph in which its original character is scarcely perceptible.

But there is another and higher plane of human life. The "*Struggle for Life*" is not the only activity which nature has imposed upon man. As Prof. Drummond says it, there is a "*Struggle for the Life of Others*," just as natural and scientific as the other.

This plane is the plane of altruism or philanthropy. It begins in the mother's struggle for her child, and mounts step by step to the father's toil for his family, the friend or neighbor's regard for his neighbor; the patriot's love for his country, and the philanthropist's efforts for humanity.

Let me entreat you, when you take your places in our midst to begin your work and career, do not join the ranks of the selfish crew, who sneer at and denounce the altruistic plane and phase of life as the empty dream of optimists or the cunning pretense of tricksters. Mother-love, patriotism, and philanthropy are not tricks or dreams. They are great facts growing out of the elements of human nature as logically as the arts of civilization have grown out of the primal need for food and shelter.

History owes its grandest pages to these principles of man's altruistic love for his country and his kind. His battles for the right, and against oppression and the wrong, are not parts of the struggle for others.

The movement now in the air for municipal betterment and for civic reform, honors mankind because it is so purely altruistic.

Avoid selfishness, that you may obtain higher spiritual worth. Struggle not only for yourself, but for the life of others. Be patriotic lovers of your country. There is a cry on both continents for better municipal government, and no young men are better equipped for this great work than you, with your technical knowledge of railroads, machinery, and all the forces that are now so essential to our existence.

To these great sociologic movements we ask your brain and hand. Come to our help and rescue, as we fight these last and grandest battles of civilization and of humanity.

But does our work stop here? Does selfism and other-selfism, the soul and society, comprehend all of humanity?

As Guizot, that great French historian, wrote: "Where the

history of civilization ends, when there is no more to be said of the present life, man invincibly demands if all is over—if that be the end of all things? This, then, is the last problem, and the grandest to which the history of civilization can lead us."

Is not the key to this problem offered us by Him, who so loved the world that He gave Himself a ransom for it?

The Kingdom of God or of Heaven, of the True, the Good, the Beautiful, the Divine is above and beyond.

On this last and highest plane man also lives and works. Here spring and grow the poet's loveliest dreams, the statesman's loftiest ideals. Here stands out as the ultimate truth the Fatherhood of the Eternal, the divinity of man.

Finally, on this three-fold plane of life, comprehended in the two great laws to which the Founder of Christianity lent his most sublime and strongest sanction, your own good, as well as ours, binds you all.

"Lives of great men all remind us
We can make our lives sublime,
And, departing, leave behind us
Footprints on the sands of time.

"Footprints, that perhaps another
Sailing o'er life's solemn main,
A forlorn and shipwrecked brother,
Seeing, shall take heart again."

The degree of Mechanical Engineer was then conferred by Mr. S. B. Dodd, President of the Board of Trustees, who handed their diplomas to the members of this, the largest class yet graduated from Stevens. The names of the graduates and the subjects of their theses are given below.

GRADUATES RECEIVING THE DEGREE OF MECHANICAL ENGINEER.

SUBJECTS OF THESES.

PERCY ALLAN. G. EVERETT BRUEN. FREDERICK K. VREELAND.

Experimental Determination of the Influence of Back Pressure upon the Economy of a Condensing Compound Engine.

PEARSON ARRISON. WILLARD BROWN. RICHARD H. GUNAGAN.
Test of Engine and Boiler on Steamboat *Calvin Tompkins.*

D. D. BARNUM. WILLIAM H. CORBETT.
Analysis and Test of Shaft Governors.

THOMAS E. BUTTERFIELD. FREDERIC D. OGDEN.
Review of the Stresses and Proportions of the Central Span of the Poughkeepsie Bridge.

LATTIMORE CARTER. EDWIN HUTCHINSON. EDWARD W. ROBINSON.
Test of Cold Storage Plant at Newark, N. J.

AUSTIN CHURCH. CHARLES T. CHURCH. EDMUND KEMBLE.
Comparative Test of Three Types of Boilers—Babcock, National Water Tube, and Corliss Upright.

STUART COOPER. ROBERT E. HALL. CHARLES P. PAULDING.
Plan and Estimate for the Improvement of the Water Power at West Point Foundry and Introduction of Electric Transmission.

MORGAN S. CRAFT. THOMAS B. CUMING. FREDERICK R. SMART, JR.
Efficiency Tests of Different Gas Burners and of Oil Lamps.

ALBERT F. GANZ. FREDERICK N. TAFF. LAURIDS C. SORENSEN.
Test of the Morris County Electric Company's Lighting Plant at Morristown, N. J.

CHARLES AUSTIN GREENIDGE.
Experimental Tests of Non-conducting Materials for Covering for Steam Pipes.

ALEXANDER K. HAMILTON. ARTHUR E. WOOLSEY.
Performance of Twin Screw Steamer *City of Lowell.*

JAMES B. HAMILTON. A. R. WILLIAMS.
A Comparative Test of a Blake Compound Direct Acting Steam Pump and a Single Acting Pump for Boiler Feed.

EDWARD M. HARRISON, JR. CHARLES J. SLIPPER. EDWARD C. SCHMIDT

Relative Heating Powers of Coal by Direct Experiment and Comparison with Calorimeter Tests.

GEORGE P. HODGMAN.

The Relative Merits of Pneumatic and Electric Transmission of Power in Railway Shops.

GUY HOPKINS.

Calorific Intensity of Coal.

BETHEL H. JACKSON.

Power Absorption by the Water Rheostat.

THEODORE E. JEWELL.

Design of a Floating Grain Elevator.

FRANK V. LAWRENCE. FREDERICK W. WALKER.

Test of the Edison Electric Illuminating Plant, Brooklyn, N. Y.

G. ARTHUR LENSSEN, JR.

Comparative Determination of the Permeability of Iron by Various Methods, in Particular by Means of Alternating Currents.

FRANK N. MACVEETY. WILLIAM W. WARD.

Investigation of Line Losses in a Trolley System.

HOWARD H. MAXFIELD.

Review of a Highway Bridge at Worcester, Mass.

NESTOR RAMIREZ.

Test of Refrigerating Plant at the Reading Terminal, Philadelphia, Pa.

H. C. ZIMMERMANN.

Test of Boiler and Engine of Tug *Peter S.*

Mr. Dodd announced that the Stevens School Scholarship had been this year awarded to two competitors, Messrs. R. C.

Aldrich and F. B. Sanson, on account of the high and close averages, 98.2 and 97.7, respectively earned by them.

Mr. Wm. H. Corbett followed with the valedictory. His address, which is given herewith in full, was received with hearty applause.

Valedictory Address.

"Mr. President, Gentlemen of the Board of Trustees and of the Faculty of Stevens Institute of Technology, Friends, Classmates:

"The final page of the history of our class as a corporate body, is about to join its predecessors in the rank and file of the past. The machinery of Stevens has again completed its cycle, and another little group of ambitious youths, clothed in the dignity bestowed by the degree received to-night, is pausing on the threshold of a future, which impartially yields its allotment of joys and sorrows, triumphs and disappointments, to each and every one. The portals which to-night close on the collegiate existence of our class separate us from a group of opportunities, a succession of events, and an atmosphere of influence, the effect of which will survive the processes of time and exist as a most cogent factor in our future career. Yesterday we were students reveling in the thought that the far distant goal, which held us steadfast through the rugged steeps of our infant college efforts, was at last within our reach. To-day we glory in the sweetness of our victory. To-morrow we will be graduates, face to face with the stern realities of life, before which the glittering dreams of fanciful youth lose their splendor and their potency. The time is at hand when the little battalion of recruits, who have been drilling away striving to master the principles which must be brought to bear in subduing the forces of nature to the will of man, will receive their appointments, and for the time be lost to view in the immensity of the engineering field. Here, as common soldiers in the ranks of the mighty army of engineers, we will find ourselves side by side with the trained cohorts from other institutions of grander proportions than our own. Youthful conceits will be shattered, visionary dreams will be subject to rough awakenings; but still, actuated by similar

ambitions and educated in the light of the one broad creed which binds the devotees of engineering together, these comrades will struggle forward with the laurel wreath of success stimulating every faculty which can be brought to bear. Then comes the crucial test of the student's training, and if the Stevens man of the '95 product sustains the established reputation of the past, the flight of time will not be long ere from the serried ranks of struggling men, leaders will be chosen whose success will warm the hearts of those who honor us with their presence to-night.

"And yet in the order of nature it has been arranged that failures must come, and far be it from my wish to picture an ideal future of transcendent success, such as has never yet crowned the efforts of man. The possibility of the fulfilment of the hopes and stimulating resolves which are dominant in our hearts to-night would doubtless pronounce this class to be the most brilliant in the annals of history, and yet we are but like unto other bands of classmates who have listened to the honeyed words which foretold distinctions which have yet to be realized. Rather than let the untutored vision of youth fall unto the unknown future, let us turn to the more immediate duty of thanking those who have equipped us with the weapons of knowledge to face that future with calm mien, and bid them Godspeed in the continued performance of a duty which should crown their latter days with the proud satisfaction of a worthy mission well accomplished.

"Mr. President, in thanking you for the precious opportunities which we have received under your direction, we feel that no praise, however unstinted, would be unmerited. The stores of your learning, the courtesy and liberality of your nature, and your keen sense of justice, have ever been at our disposal and worthy of our respect and gratitude.

"To our literary venture you have contributed the talents of your mind, and in the financial straits of our athletic status the talents of your purse have been generously in evidence. Students' demonstrations founded on equity and fairly presented have been recognized and sustained; while those of a contrary order have been as quickly recognized, but as summarily disposed of, proving that the vigor of the disciplinarian

was not subverted by the benign thought of the educator. In the social walks, which have offered their delightful periods of relaxation, you have joined forces with the one who has so richly blessed you with life companionship, and offered charming little bowers for rest and enjoyment.

"In short, you have been our master, our counselor, and our friend. By the aid of your example we recognize the old adage, that 'actions should be valued by their utility rather than by their splendor,' and with a wealth of gratitude, and severe pangs of regret, we bid you farewell.

"Gentlemen of the Faculty, captains of the various ships which have safely brought us our store of knowledge, receive our thanks for your watchful guidance, which permits us to stand here to-night. Having heard the encomiums of two of my predecessors in your behalf, it would seem impossible to further accent your individual virtue and composite greatness, as outlined in the very splendor of their asserted opinions.

"It must have been the magnificent qualifications therein portrayed, which have made us appreciative of each other; for some of the more enthusiastic members of your body have allowed their unbounded admiration for our class to find expression in the history of the Institute, in fact, that we are the best on record. Whether the distinction was gained by our rapid absorption of knowledge, or by lack of inventive genius devoted to the pleasant diversion of making life miserable for our professors, matters little, since in either case joy has been infused into your hearts. We would not have you stand alone in your happy expression of esteem, and we frankly confess that you constitute the finest faculty which has ever presided over the dissection of our lofty flights of intellect. If your evident appreciation of our scholarly demeanor has lured us from the paths of modesty and led us to conceive and present new plans for the operation of your various departments, mercifully attribute it to the growth of greatness consequent upon your watchful instruction. One of the sage counselors in your midst has truthfully remarked that an opinion of your past efforts in our behalf twenty years hence, is the time exponent of their value, and to such of you as by God's grace are permitted to span the period of continued life, we doubt not that the blessing of rewarded effort will be yours.

"The course which you have made celebrated has, by virtue of pressing needs, not been supplanted by the luxuries of funds which are at the disposal of your compeers in some similar institutions, but yet you have verified the truth of Webster's declaration that 'costly apparatus and splendid cabinets have no magical influence to make scholars.' That you *have* made scholars in the past is amply vouched for by the prestige of Stevens to-day. That you may continue in the life's work which is founded rather on the love of science and mankind than the hope of personal aggrandizement, is the desire of those who now wish you Godspeed.

"Classmates, companions of the most delicious portion of man's life, it is now my solemn duty to bid you farewell. The friendships which have been formed by four years of constant association are the dearest which ever fall within the circle of human existence. During this long but rapidly fleeting period of companionship, the heart has learned to feel the rich blessedness of true friendship, and the thought that the hard, prosaic duties of mature manhood are about to thrust their diverting influence between our treasured fellowship, tinges the graduate joy with a shade of sadness. The stereotyped words of praise and appreciation are no longer valid performance of my task, for the spontaneous promptings of the heart usurp the measured dictates of the mind.

"Among those who graduate this evening are just half of the original class of '95, as it first assembled and started the joint process of gaining knowledge and muscle by alternate contacts with the professors and the Sophs. The stint of aggressive progress which was manifested in those Freshman days has clung through the course and is even now inspiring you with a fearless contemplation of which lies before. And yet the independence of thought and action which you have shown, has offered no barrier to the amicable and dignified settlement of the inventors' questions which have presented themselves for your disposal. Party issues have not ruled, and clannish combinations have to a small extent perverted the honest expression of your opinion.

"The odious spectacle of class disruption has never subjected us to the scorn of our elders or poisoned the example

for those who follow. These thoughts which come back to me as I look over the record make me proud and happy to think that in the future I shall be able to cherish recollections of my college life which shall be bright and filled with little incidents, the review of which will bring no pangs from half-healed wounds, but rather sweet commingling of delightful memories which, softened and blended by time, affords mankind one of the chief means of crowding that which is hard and worldly from the mind. Nor will memory be our sole aid, for on the numerous voyages through life our paths will frequently intersect, and the two travelers will for a time sail along side by side and revel in the renewed friendship which brings back the spirits of the good old days.

"And now, my classmates, the time of parting is at hand, the final class roll-call has been answered, and the commencement of our real life begins. That your course down the wider and deeper stream of manhood may be attended by the encouragements of success and the blessedness of a true and faithful life is my most fervent hope. A chapter of our life is rounded off and completed; ties, many and cherished, are severed and the word which makes us linger is at hand. Classmates, I bid you an affectionate farewell."

The Rev. Mr. Jenvey then pronounced the benediction, and the men who had now finished their student life at Stevens hastened to receive the greetings of waiting friends.

Messrs. Edward C. Schmidt, Frederick K. Vreeland, and Percy Allan constituted the Commencement Committee.

The Reception Committee was composed of the following members of the Junior class: Wallace Willett, William T. Rasmus, Henry M. Hardie, William H. Jennings, Edwin L. Decker, and W. Cullen Morris.

The Glee, Mandolin, and Banjo Clubs, under the leadership, respectively, of Messrs. MacGregor, '96, Evertz, '96, and Barnum, '95, contributed several numbers to the musical part of the program, to the evident delight of the audience.

ANNUAL MEETING OF THE ALUMNI ASSOCIATION OF STEVENS INSTITUTE, HOBOKEN, JUNE 19, 1895.

The annual meeting of the Alumni Association of Stevens Institute of Technology, held in the hall of Stevens' School, was called to order by President Hewitt.

It having been announced that the minutes of the previous meetings were printed in full in the INDICATOR, it was moved, seconded and carried that the reading of the minutes be dispensed with.

The treasurer, Mr. W. H. Bristol, made the following report, which, on motion, was accepted:

TREASURER'S REPORT.

HOBOKEN, June 19, 1895.

To the Alumni Association of the Stevens Institute of Technology:

I. GENERAL FUND.

Receipts.		
Balance in Fund June 20, 1894	$ 8 34	
Dues for 1894–95	760 00	
Dues in arrears	132 50	
Dues in advance	12 50	
		$913 34
Expenditures		
Alumni subscriptions Stevens' INDICATOR, to June, 1895	$680 00	
P. E. Raque, corresponding secretary, printing, postage and clerk hire	71 22	
W. H. Bristol, treasurer, printing, postage and clerk hire	35 75	
Expenses, annual meeting, June 20, '94	4 00	
Expenses, midwinter meeting, February 20, '95	115 75	
		906 72
Balance June 19, 1895		$ 6 62
Dues in arrears June 19, 1895		969 00

II. BENEFICIARY FUND.

Receipts.		
Balance in Fund June 20, 1894	$867 33	
On loans repaid	182 04	
Interest on loan	3 22	
Bank interest to Jan. 1, 1895	29 98	
		$1082 57
Expenditures.		
Loans	$150 00	
Temporary loan to INDICATOR	600 00	
		750 00
Balance in Fund June 19, 1895		$332 57
Amount of outstanding loans		625 19

III. LIBRARY FUND.

Balance in Fund June 20, 1894	$114 75	
Balance in Fund June 19, 1895	114 75	

IV. LIBRARY PORTRAIT FUND.

Balance in Fund June 20, 1894	$1 72	
Balance in Fund June 19, 1895	1 72	

V. STEVENS' "INDICATOR."

Receipts.		
Balance June 20, 1894	$243 77	
From Prof. Graydon, Business Manager	603 71	
Alumni subscriptions to date	680 00	
Loan from Beneficiary Fund	600 00	
		$2127 48
Expenditures.		
Publication April INDICATOR, 1894	$257 77	
" July " 1894	307 70	
" Oct. " 1894	210 32	
" Jan. " 1895	410 58	
" April " 1895	298 73	
Prof. Graydon, editing INDICATORS from April, 1894, to July, 1895	250 00	
Drawings and cuts for INDICATORS	155 28	
Reprints	66 00	
Typewriting	5 75	
Commission on advertisements	16 25	
Indexing	43 46	
Binding INDICATORS	20 40	
Stationery	28 50	
Sundries per Managing Editor	55 03	
		2125 77
Balance June 19, 1895		$1 71

Respectfully submitted,

W. H. BRISTOL, Treasurer.

In addition to his financial report, Mr. Bristol announced the names of several members who are more than three years in arrears for dues, and who have been dropped from the roll in accordance with the provisions of the constitution.

Mr. Humphreys asked for informnation concerning the loan to the INDICATOR from the Beneficiary Fund, and Mr. Graydon stated that it was made from a balance lying in bank

to enable the INDICATOR to meet its bills promptly in advance of collections for advertising which would not be due until July or later. Outlay on the INDICATOR had been unusually heavy in the early part of the year, owing to the "Index of Engineering Literature" and other features introduced, when there appeared a reasonable probability of larger returns from subscriptions than have materialized. On the other hand, the advertising account has been increased about $300 this year. The outlay for the remaining numbers of the volume will be much less the previous ones, and there is a reasonable prospect that the loan will be required for but one year.

Prof. Riesenberger reported the status of the Building Fund, as follows:

The Fund on June 1, 1894, was	$ 9,681.11
" " 1895, "	11,319.08

The total amount of the Fund to date, including accrued interest, is about $12,000.

On motion, the report was accepted and ordered spread on the minutes.

Mr. Flack, Secretary of the Executive Committee, made the following report:

MR. PRESIDENT AND GENTLEMEN OF THE ASSOCIATION:

Your Executive Committee desires to report that it has held a number of meetings during the past year, for the purpose of transacting the necessary business of this association.

The midwinter meeting was arranged for, and your committee feels very much gratified at the result. The attendance of the Alumni at this meeting numbered 79. The invited undergraduates numbered 36. The large attendance and general good time which prevailed, shows an increasing interest in these meetings. The committee feels indebted to the Glee, Mandolin and Banjo Clubs of the undergraduates for their aid in the entertainment, and considers itself fortunate in having such resources to call upon.

Your committee has the following resignations to report: R. M. Riddle, '81; Leon Greenbaum '85; Jas. B. Adger, '83. One of the borrowers from the Beneficiary Fund has been

long in arrears, and your committee desires to report the fact for such action as you deem proper.

J. DAY FLACK, Rec. Secy.

Several members expressed their views as to the wisest action to be taken in the matter of the debtor to the Beneficiary Fund, and on motion, duly seconded, it was resolved to refer the matter back to the Executive Committee for further investigation.

In the absence of Mr. Wolff, the retiring Alumni Trustee, Mr. Durand Woodman reported for the Alumni Trustees, that the financial status of the Institute was good, and that the material acquisitions to the Institute this year, have been three additions to the machinery of the Department of Electricity; one being a dynamo machine adapted to yield a current of large volume at moderate potentials, and developing about twenty electrical horse-power, presented by President Morton; another, a thirty horse-power Payne engine, and a biphase electric motor, presented by the Class of '95. The Institute has also received a model, in metal, of a Buckeye engine, presented by the Buckeye Engine Co.

On motion, the report was accepted and ordered spread on the minutes.

The following letter from Mr. A. R. Wolff, was handed the Secretary after the close of the meeting, too late to be read.

To the President and Members of the Alumni Association, Stevens Institute.

GENTLEMEN:—It has been my intention to be with you this evening, to say a few words as Alumni Trustee, but a matter has arisen which makes it imperative for me to leave town, and does not enable me to be present at to-night's meeting. Please accept my expression of regret, and my apology that I cannot join in your deliberations and in the renewal of good-fellowship and friendship which marks these occasions.

Things run so smoothly at the Institute under the wise, judicious, and energetic management of our self-sacrificing President Morton, aided by the equally earnest efforts of the Faculty, that the office of Alumni Trustee represents one mainly

of honor, unalloyed pleasure, and very little work. But perhaps this is the most gratifying report that a trustee can give, that everything is in such excellent condition, and is being so wisely managed, that there is no demand for his taking an active part in the management, except to note how things are going, and to appreciate that they are going well. In one sense, the finances of the Institute are in excellent condition—that is to say, during my three years' service there has been each year an increase, though comparatively small, in the capital of the Institute, occasioned mainly by the fact that the high school is a paying institution, and that its net income exceeds by a few thousand dollars the small deficit which the Institute proper shows every year. It is remarkable how much is being done in the Institute with the capital and income at command, a fact which must come home to all of us when we are aware that the actual capital of the Institute is very much below one million dollars. In these days of donations of a million dollars for individual buildings, it is patent that a total capital of considerably less than one million dollars is very small for an institution of the standing of Stevens, and one doing the amount of work. It is well to bear in mind, both in justice to the remarkable results achieved and also from the point of view that there is danger attached to the husbanding which comes from having a small capital, that the capital is so small, and it is to be sincerely wished that there may be, by bequests or other means, a decided increase in the available funds.

The work which is being done at the Institute is of a high order, and I think that it is a conservative statement to make, that no other institution of engineering in this country, despite greater facilities of capital, is ahead of Stevens, or, indeed, equal to Stevens in the work accomplished. This result is due, as I have already said, to the ability and self-sacrifice of the President and his associates in the Faculty, and also to the character of students who find a congenial atmosphere in Stevens' halls. It is the character of men that are turned out, and the work they do in actual life, which determine the character and standing of an institution, and determine whether it is a success or not. Gauged by this standing, and the appreciation, name and even fame which Stevens' graduates have won, the Institute is

certainly a success, and its leaders are to be congratulated on the achievement.

At the meeting of the Board of Trustees yesterday evening it was decided to institute some lectures by some competent patent lawyers on patent law—not with the idea of entering this subject in any detail, but to present the great underlying principles sufficient to put the graduates on their guard, so that they will know enough to seek proper protection for the inventions which they may make, and not find themselves without the legitimate profit which their inventive ability and skill should demand, but which a defective patent may cause them to forego, as has been the experience of not a few of Stevens' graduates in the past. It is also intended to have a few lectures on methods of keeping shop accounts, so that the young men, on graduation, may have some little insight into the principles which underlie this subject.

It has also been decided to invite, to the reasonable degree which the already crowded course of the Institute will permit, a few graduates to deliver a lecture or two on some specialties which they are competent to discuss, and it is believed that the graduates will only be too glad to meet this demand without any compensation.

Mr. George M. Bond has been elected an Alumni Trustee to fill the vacancy occasioned by the expiration of my term, and it gives me, individually, pleasure to know that so far more competent a man is now in office.

Thanking you for the many honors which you have conferred upon me in the past, the greatest of which was to be one of your representatives in the Board of Trustees, I have the honor to be, Sincerely yours,

ALFRED R. WOLFF.

As the Executive Committee had not elected the Class of '95 to membership in the association, the matter was now brought up, and, on motion, the Secretary cast the necessary vote admitting the class to membership.

President Hewitt then read his address, which was followed with close attention, and received with hearty applause.

PRESIDENT HEWITT'S ADDRESS

I believe it is the privilege of your presiding officer upon

retiring, although it may not be the invariable custom, to make some remarks: I will not attempt to dignify what I have to say by calling it an address, as I prefer to follow the path marked out for me by nature, habit and inclination, and make simply a few remarks, and these from the fulness of my heart. I could not let this occasion pass without thanking you for the great honor in nominating me to represent you on the Board of Trustees, and I take this occasion also to thank the Board of Trustees for the further honor in selecting me to fill that position. I regret to say that I have only been able to attend one of the meetings of the Board, and also, that circumstances were such as to prevent me from attending the last annual meeting of this society and reporting to you. There was little or nothing to report, however, beyond the fact that the affairs of the Institute were in good shape.

Your selection of me as your presiding officer at this time, I take it, is in a measure a recognition of the distinction which I hold of being one of the earliest of Stevens graduates, and also of the fact that it is just twenty years since I had the pleasure of presiding over the the initial meeting of this association. That I should be called upon again to that position at a time when the association numbers nearly five hundred members is very gratifying, and a further evidence of your esteem that I am deeply sensible of. I can scarcely realize that twenty years have passed since that modest gathering in the old lecture hall, and doubt if any of those composing that gathering had formulated then any very definite ideas as to the true functions of an alumni association, or at least realized what was to be the outcome of that meeting. Other institutions of learning had their alumni societies, and of course we were not to be behind them in that respect. The social feature of the occasion naturally assumed paramount importance, and the business of organization was hurried through in anticipation of the dinner to follow. That was the great event, and is still a very pleasant accompaniment of these gatherings. But we are twenty years old tonight; almost of age, and having arrived at years of discretion, as I may say, it behooves us to consider seriously what we are here for.

The Constitution states in Article II. that "the object of

this association shall be to cultivate such social relations as shall tend to foster among its members a sentiment of regard for one another, and of attachment to their Alma Mater, and to promote in every way, the interests of the Institute."

If I had the writing of this section now, I do not know that I should put it exactly in that way. I have always supposed that duty came before pleasure, and think, therefore, that the interests of the Institute should take precedence of sentimental regards. I do not wish to be understood, however, as suggesting any change in the phraseology of this section. It answers the purpose very well as it is, and is a concise statement of the objects of this association.

As the years roll by the social ties become less binding. We miss faces that used to be familiar to us on these occasions. Death has laid his grim hand upon us, but sparingly as yet. It is distance that renders it impossible for a large majority of the members to attend these meetings, and while it may be very pleasant to make new acquaintances, these can hardly fill the places of absent comrades, so that these gatherings may have lost a certain interest to some of the older members that they possessed in former years. Members residing within easy access of the Institute, however, will scarcely need to be reminded that they owe an allegiance to their Alma Mater; that should prove a sufficient lodestone to draw them here, were there no other sources of attraction.

The utility of this society is whatever the members choose to make it. *Per se*, the society may confer no direct benefit upon any of us beyond that to be derived by the comparison of each other's experiences, and the value of this is not to be underestimated by any means; but with a membership as scattered as ours must always be, this advantage is necessarily confined to those who are so favorably situated as to be able to attend these meetings regularly, and for this reason also must devolve upon them mainly the management of the society. The INDICATOR, it is true, serves in a measure as a means of disseminating these experiences, but often it is the unprinted information that is most to be desired. In serving the interests of our Alma Mater, therefore, the society perhaps satisfies our highest ambitions.

With this purpose in view, the constitution has been revised and amended on several occasions, and I believe the society now is on the right basis, as far as that goes. When the Trustees of the Institute not only accorded us a representation in their councils, but a larger representation than was asked for, and the Faculty manifests a spirit as they have on all occasions, to confer freely with us on matters affecting the interests of Stevens, it certainly should be an incentive to each and every one of us to meet them in a similar spirit, and put forth our best endeavors to advance those interests in every possible way.

Those of you in the turmoil of active business and professional careers, who must constantly witness the struggles of your fellow beings to better their condition, can well appreciate the advantages of the training you have received here, and it is well that you should pause to consider how much of your fortune or station in life is due to that training. As

You gaze on the cathedral,
  Whose turrets meet the sky;
Remember the foundations,
  That in earth beneath them lie:
For, were not those foundations
  Securely resting there,
Yon towers up could never soar
  So proudly in the air.

It may be that these foundations could have been laid so as to harmonize better with the superstructures, and this is a matter worthy of your consideration. The superstructures themselves no doubt are very interesting in their various designs, and different stages of construction; some complete, perhaps, and others but just begun; some elaborate edifices, and others but modest dwellings, for we do not all build the same. But no matter what the superstructure may be, the foundations are alike, and on that plane we know no differences, no distinctions. On that plane we gather here this evening as children about a common parent, undivided by factions let us hope, with one object in view, one purpose, and one aim—the welfare of our Alma Mater.

It is a good thing for us to meet here once or twice a year,

if possible, to look upon old acquaintances, and to greet new ones. It is a very good thing for us to keep in close touch with our Alma Mater at all times.

There are some here this evening that are strangers to me, and I crave your indulgence, therefore, for any failure in recognizing members; but I am glad to see so many present, and to note many familar faces. It calls to mind pleasant memories of days gone by. I am reminded, however, by the remarks of a former occupant of this chair, our lamented and honored comrade, Edward B. Wall, that it is with prospectives and not retrospects we have to deal, that our eyes have been given us to look ahead and not behind us. I shall not take up your time, therefore, with reminiscences of by-gone days, but would observe that, while acknowledging superior obligations to my Alma Mater, I am not one to believe that it is time wasted in living over again the old days when we were undergraduates. The cares of the present are always with us, and the future is full of uncertainties, so that I say let us have our under—— graduate days back again, but let us have them with the in—— formalities of a purely social gathering; at our midwinter meetings, for instance, which I am glad to note have assumed this character. Those of you who attended the meeting last February certainly carried away impressions of a very enjoyable occasion, and we owe a vote of thanks to the various clubs, professors and others, who entertained us so nicely then, and also to the committee who provided the subsequent collation.

It is most germane to the functions of your presiding officer, perhaps, to point out some of the ways and means, whereby the interests of the Institute may be advanced; but there are others here who are much more capable of doing this than I am, and you will pardon me, therefore, I know, if I tread lightly on this ground. The ways are plain, and have been already indicated in the reports of officers and committees (to which you have just listened). It is the means that are needed.

The lack of space and appliances for accommodating the large number of applicants for admission to the Institute, is felt quite as much now as it was when this matter was first brought to your attention three years ago, at which time a fund was

started to furnish the means for the erection of a new chemical building and for carrying out other needed improvements. The lack of these facilities has made it necessary to reject a large percentage of those who apply for admission each year, and I would therefore direct your attention to this fund as a matter of primary importance. The amount thus far realized by personal subscriptions of the Alumni and others, and from the interest on the bonds which President Morton presented to the trustees in 1892, the custodian of the fund, Mr. Riesenberger, informs us, is about $12,000. These bonds, as you know, were presented as a further endowment of the chair of Engineering Practice, with the understanding that the interest was to be applied to the building fund in question, until the necessary amount was realized, or the building paid for.

When we consider how comparatively short a time the Institute has been in existence, and the general financial depression that has prevailed for the past few years, I think the result is a creditable one. But the amount is still far short of what is required, and at the present rate of increase—about $1,500 a year—it would be many years before the full amount of $50,000 is realized. The necessity for such a fund certainly speaks well for the present management of the Institute, and if means can be employed to hasten its fruition no time should be lost in applying them. We would be glad to entertain suggestions on this matter from the Faculty or any of the members.

As far as the curriculum of the Institute is concerned, I believe this has been kept abreast of the times, and can hardly be improved upon. It appears to meet all the requirements demanded of a modern engineer, not only in the mechanical, but in the adjoining field of applied electricity also, as evidenced by the number of graduates occupying prominent positions with electrical concerns.

The Beneficiary and Library Funds, I believe, are serving a good purpose, and deserve your cordial support.

A word to the new members—the class of '95. It affords me great pleasure to welcome you among us. When I look over the Institute catalogue and note the great number of responsible positions occupied by the graduates of Stevens,

and meet them, as I frequently do, in my travels, I take much pride in the fact that I am a graduate of no mean institution, and I would have you feel that it is a good thing to be an alumnus of Stevens; that it is an honor to be a member of this association. Mr. Wall in his address very aptly likened the different classes to so many concentric rings emanating from a common center. May the ring of '95 be a resonant one, and add fresh luster to the name and fame of Stevens. You may come and I may go, but the Stevens Institute, like the brook, goes on forever, and the question that concerns you and each one of us is, shall it continue as a brook, or shall it widen into the proportions of a river, merging finally into something larger?

Whatever the destiny of Stevens, and that its destiny must be a great one goes without saying, it carries with it, beside that of Edwin A. Stevens, the name of Henry Morton. He can say truly, as Sir Christopher Wren did, when asked where his inscription appeared on the walls of St. Paul's Cathedral, London, "If you seek my monument, look about you." If you seek his monument, look about you. The equipment of the machine shop and physical laboratory, and the endowment of the chair of Engineering Practice alone would be sufficient to perpetuate his name in grateful remembrance, were there nothing further contemplated on his part. Let us hope that he and we may live to see that other monument. But whether we do or not, it is sure to come sooner or later, and whatever inscription may be graven thereon, the impress of Henry Morton will be distinct.

Mr. Graydon, as managing editor of the INDICATOR, requested an expression of opinion as to the utility of the Index of Current Engineering Literature, which had been commenced as an experiment in the January issue.

After statements by several members that they had found the index useful, and by others that such an index cannot be made as complete in the INDICATOR as similar indexes now available in some of the scientific journals, it was on motion duly seconded, resolved that the expense involved does not warrant the continuance of the index, and that it be discontinued.

Mr. Flack, for the Executive Committee, reported the result of the balloting for officers of the association as follows:

		Votes.
President	H. DeB. Parsons, '84	99
	A. W. Stahl, '76	61
First Vice-Pres	J. W. Leib, Jr, '80	79
	A. W. Burchard, '85	79
Second Vice-Pres	R. C. Oliphant, '89	95
	W. S. Ackerman, '91	65
Corresp'd'g Sec	Ph. E. Raqué, '76	149
	W. E. Parsons, '87	24
Recording Sec.	J. Day Flack, '87	127
	D. H. Gildersleeve, '89	34
Treasurer	W. H. Bristol, '84	146
	G. Henning, '76	26
Directors	A. Riesenberger, '76	111
	Kenneth Torrence, '84	90
	A. S. Miller, '88	51
	F. C. Jones, '78	35
	E. P. Mowton, '86	30
Alumni Trustee	G. M. Bond, '80	72
	E. B. Renwick, '84	18
	W. W. Dashiell, '79	17
	E. A. Uehling, '77	16
	E. P. Roberts, '77	13
	E. L. Wiles, '76	9

Mr. Flack stated that the tie vote between Mr. Lieb and Mr. Burchard had been decided in favor of Mr. Lieb by tossing a coin. He then announced that the following officers had been elected for the ensuing year:

President	H. De B. Parsons.
First Vice-President	J. W. Lieb, Jr.
Second Vice-President	R. C. Oliphant.
Corresponding Secretary	Ph. E. Raqué.
Recording Secretary	J. Day Flack.
Treasurer	W. H. Bristol.
Directors	A. Riesenberger. Kenneth Torrence.
Alumni Trustee	G. M. Bond.

Dr. Morton was then heard with lively interest. He stated that the trustees had authorized the carrying out of a plan to provide a few lectures to the senior class on patent law, sufficient to guide them in important principles and guard them from the costly errors which experience has shown ignorance of such fundamental principles too frequently entails; also to provide a brief course of instruction by lecture on shop accounts. Not that it is aimed to train students for patent lawyers or expert accountants, but to crystallize their notions on these important subjects, about correct and fundamental principles.

The growth of the Building Fund is not at all disheartening to contemplate; and, as the change in the business conditions of the country is ushering in a sense of relief and encouragement, it is probable that ere many months plans in mind for a second substantial start toward the aim of this fund will take tangible shape.

The action of the Sophomore class in substituting for the noisy demonstration of former occasions of Cremation of Calculus, the entertaining and meritorious display enjoyed by those who witnessed the Electrocution of Calculus, as presented this week by the class of '97, is another step in advance originating within Stevens, one which the participants and all friends of Stevens may well take pride in.

He told, laughingly, how the result of his investigations into the recent little occurrence which had so extensively advertised the class of '98 in the newspapers, had suggested the possibility that the members of that class had heard that it was rumored that some one was going to meet the young men who were expected to present themselves for entrance examinations on a certain day and have a little fun at their expense. That thereupon the members of this class, each for himself, individually, and without preconcerted agreement or arrangement, determined to be on hand and see to it that nothing boisterous or unruly be done, or any dubious welcome be extended to the incoming strangers. If such were the motive it was unfortunately forgotten, and in consequence some there were that suffered.

Dr. Morton, referring to the decision of the Executive Committee arrived at by tossing a coin to determine which of two candidates receiving an equal number of votes should be de-

clared elected, said this was an added cause to the many he felt for great pride in the achievements of Stevens Alumni. Had the justices of the Supreme Court enjoyed a like broad yet practical education, they would possibly have availed themselves of the same method of reaching a decision on the income-tax question, and not have occupied the ignominious position which gave rise to the opinion that the Supreme Court of the United States does not know its own mind.

But in all earnestness, would he express the feeling of pride arising from the character and rank of the INDICATOR, favorable notice of the articles in which had reached him from Mr. Dredge, editor of London *Engineering*, and from other sources. The April number was one of which the Alumni may feel proud; even the character of the advertisements is noteworthy as coming, with very rare exceptions, from representative engineering concerns.

Mr. Kent was called on and responded briefly, after which a motion to adjourn was carried.

The following were present:

President Henry Morton,
Professor Charles F. Krœh,
" William E. Geyer,
Asst. Prof. Adam Riesenberger,
" William H. Bristol,
" D. S. Jacobus,
" Samuel D. Graydon,
" Robert M. Anderson,
William Hewitt, '74,
James M. Cremer, '76,
Gustavus C. Henning, '76,
William Kent, '76,
Frank E. Idell, '77,
Edward A. Uehling, '77,
Arthur A. De Bonneville, '78,
John W. Lieb, Jr., '80,
Durand Woodman, '80,
Alexander C. Humphreys, '81,
Joseph Wetzler, '82,
George L. Roberts, '84,
Rollin Norris, '85,
William N. Stevens, '85,
Charles R. Collins, '86,
John S. De Hart, Jr., '90,
William Ebsen, '90,
W. F. Lawrence, '90,
Benjamin W. Carll, '91,
Alfred J. Dixon, '91,
Harold B. Atkins, '92,
Frederick Gardiner, '92,
August R. Hake, '92,
Frank E. Law, '92,
Herman Lowenherz, '92,
William O. Ludlow, '92,
Louis F. Waefelaer, Jr., '92,
Harry H. Adams, '93,
O. G. Dale, '93,
F. D. Furman, '93,
E. D. Lewis, '93,
A. B. Lord, '93,
Anson G. Wilbor, '93,
George W. Colles, '94,
Edward Gnade, '94,
C. C. Kenyon, '94,
C. W. MacCord, Jr., '94,
E. D. Mathey, '94,

J. H. Cuntz, '87,
J. Day Flack, '87,
Eugene H. Kiernan, '87,
William E. Schoenborn, '87,
Henry A. Bang, '88,
Gordon Campbell, '88,
George Dinkel, Jr., '88,
Paul Doty, '88,
Alten S. Miller, '88,
Fritz Uhlenhaut, Jr., '88,
Henry L. Ebsen, '89,
William D. Hoxie, '89,
Robert C. Oliphant, '89,
Shirk Boyer, '90,
R. W. Smith, '94,
Willard Brown, '95,
Austin Church, '95,
C. T. Church, '95,
Albert F. Ganz, '95,
C. A. Greenidge, '95,
R. E. Hall, '95,
E. Hutchinson, '95,
Edmund Kemble, '95,
Howard H. Maxfield, '95,
E. W. Robinson, '95,
E. J. Slipper, '95,
Frederick W. Walker, '95,
H. C. Zimmermann, '95.

Obituary.

JOHANN M. HANSEN, '91.

The members of the Class of '91, the Alumni and the Faculty, will regret to learn of the death of Johann M. Hansen, which occurred on July 23, at the Catskill Mountains, after a lingering illness, of consumption.

Johann M. Hansen was born in Svendborg, Denmark, on February 22, 1870, being the youngest son of Johann M. L. and Johanne Catherine Hansen. He attended the Svendborg High School until 1881, when, upon the removal of his family to Copenhagen, he entered the Copenhagen Lyceum, from which he graduated with highest honors, prepared to enter the University at Copenhagen. Subsequently the family moved to America; and, instead of attending the University at Copenhagen, he entered Stevens Institute in the sophomore year of the Class of '91, and graduated in June, 1891.

He was a student of more than ordinary ambition, having devoted himself in his earlier career to astronomy and mathematics, and later took up the more practical professions of general engineering. He graduated with high honors, and devoting himself to the study of water-gas production, was employed by the United Gas Improvement Company, of Philadelphia, superintending the erection of eight gas plants in various sections of this country. Mr. Hansen received the Priestly prize for his proficiency in chemistry during the sophomore year, and this knowledge of chemistry made him of invaluable service to his company, the United Gas Improvement Company, of Philadelphia, as an expert in this class of work, being a good gas chemist and photometrician and expert gas

maker. He was a young man of highest promise and endeared himself to all with whom he came in contact, and was popular among his associates, who admired him for his honesty of purpose and simplicity of character. His gentle manner and kindness made him one of the popular students in his class, and many tears were shed when his sudden death became known.

Had Mr. Hansen been spared he would have been a great credit to the Institute and to the profession he chose to follow.

He was buried in the Hoboken cemetery, the funeral services at his home being after the rites of the Danish Lutheran Church. At his grave fitting remarks were made by L. E. Elson, '91, one of his classmates. The funeral was very impressive, his aged parents being present, as well as his attentive sisters, who had devoted themselves to nursing him during his long illness. His inborn love of the Fatherland made itself manifest by his request to be encoffined in zinc, so as to allow of the removal of his remains to Sweden, in the event of his family returning there.

JOHN HEBER MURRAY, '92.

John Heber Murray was born at Milton, Pa., June 24, 1868. In 1884 he entered the Preparatory School of Dickinson College, Carlisle, Pa., and in 1885 the freshman class of that college, from which he was graduated in 1889. In 1889 he entered the sophomore class of Stevens Institute and was graduated in 1892. In the same year Dickinson College conferred upon him the degree of A. M., in course.

He was married to Margaret Bosler, of Carlisle, Dec. 23, 1890, by whom he had one son, Samuel Wilson Murray, Jr., born Oct. 17, 1893. At the time of his graduation from Stevens Institute his health was impaired; and, during the summer, in company with his wife and father, he made a short trip to Europe, from which he returned apparently restored. In the lat-

ter part of the year 1892 he accepted a position in the engineers' office of the N. Y., N. H. & H. R. R., which he was compelled to resign in the following spring, owing to an affection of the eyes. During the summer of 1894 he was employed by his father at Milton, and, although able to attend to his duties, it was evident that he was not in the enjoyment of his previous health and vigor. In September, on his return to Carlisle, where his family was then living, he was taken down with what was supposed to be malarial fever, but which developed into tubercular consumption. In the month of April, 1895, accompanied by his physician and his father, he took a trip to the South, hoping that the change to a warmer climate might prove beneficial. After spending a few weeks at St. Augustine, Florida, and Summerville, S. C., he returned to Carlisle without any improvement in health. From this time he failed rapidly and died at Carlisle June 18, 1895, his wife and son surviving him. His remains were taken to Milton for burial.

ATHLETICS.

LACROSSE.

At the beginning of the season now finished, the hopes of the supporters of Stevens ran high. Stevens had won the Intercollegiate Lacrosse Championship the year before. Could she retain it this year? We thought so. But we were destined to disappointment. This year we hang no new banner on our library's walls. The championship has gone to the men from Bethlehem, and the banner now graces the walls of Lehigh. No blame can be attached to the men who represented Stevens. They worked hard and faithfully, and succumbed only to fate and "Stevens' luck."

The games played were as follows:

April	19,	at Berkeley Oval;	Stevens 1,	N. Y. U., 5
"	24,	" Hoboken;	" 1,	Crescent A. C., 1
"	30,	" "	" 9,	C. C. N. Y., 1
May	4,	" Manhattan Field;	" 3,	Harvard, 2
"	8,	" Hoboken;	" 8,	C. C. N. Y,, 0
"	11,	" Baltimore;	" 3,	Johns Hopkins, 6
"	14,	" Hoboken;	" 3,	Cornell, 2
"	25,	" "	" 1,	Lehigh, 6
"	30,	" Bergen Point;	" 1,	Crescent A. C., 4

STEVENS *vs.* NEW YORK UNIVERSITY.—The lacrosse season was opened by a game with New York University at Berkeley Oval. The score was against Stevens, but any other result could hardly have been expected. Six men of our team were playing their first game, while the N. Y. U. team was composed of veterans. In fact, but three of them were *bona fide* students of N. Y. U., the rest being old players from the N. Y. A. and Manhattan teams, together with three or four Canadian players. In the first half of the game the play of Stevens was very ragged, but in the second half they pulled themselves together and played very creditably.

It was difficult to get the names of the N. Y. U. team; but, thanks to a revision by an expert lacrosse man present, a few correct names were obtained.

N. Y. U.	POSITIONS.	STEVENS.
F. A. Sutorious	Goal	Willett, '96.
Grant, alias Hollner	Point	Corbett, '95.
Page, alias Pape	C. Point	Whitman, '96.
De Casenover	1st Defense	Maxfield, '95.
Franklin, alias Mansfield	2d "	Hunter, '97.
Nelson	3d "	Kennedy, '96.
Davis	Centre	Bruen, '97.
Harkin	3d attack	Christy, '97.
Kelly, alias McAlpie	2d "	Bruckner, '96.
P. F. Sutorious	1st "	Jennings, '96.
Greenbaum	Outside Home	Scott, '98.
Whiting	Inside "	Weichert, '97.

Referee—F. J. Adams.

Umpires—{ C. Steinhart, Columbia. / Messimer, '96, Stevens.

2 thirty-minute halves.

Goals—4 for P. F. Sutorious.
1 for Whiting.
1 for Scott.

Score—5—1 in favor of N. Y. U.

STEVENS *vs.* CRESCENTS.— Stevens this year played two games with the Crescent A. C., the second game of the season and the last. In the first game the work of Stevens' team was very creditable. They played hard and fast, and showed considerable skill in passing and body checking. The score, as against the veteran team of the Crescents, was better than had been expected. In the second game Stevens played a team almost half of whom were substitutes, and, owing to the tremendous heat of the day, their playing was slow and spiritless.

STEVENS *vs.* C. C. N. Y.—The two games which we played with C. C. N. Y. cannot be considered other than practice games. In each game, many members of the second team were given a trial, and Stevens was not once obliged to make any real effort to win.

STEVENS *vs.* HARVARD.—In the game with Harvard, an experiment was tried by Stevens, and it is to be regretted by every supporter of Stevens and lover of lacrosse, that the experiment was not successful. Despite the faithful work of the management, the attendance was very poor, and the receipts fell short by a considerable amount of meeting the expenses connected

with the hiring of Manhattan Field. Otherwise than financially, the game was all that could have been desired. Though small, the attendance was enthusiastic, and the fine work of the players well merited their applause. In the first half of the game, the team work of Harvard was noticeably superior to that of Stevens, but Stevens' strong defense, and the fine stick handling of the whole team, overcame, to a great degree, this advantage. At the end of this half, the score stood 2--1 in Harvard's favor, one of their goals having been accidentally thrown by Maxfield.

In the second half, Stevens played their hardest, and Harvard tried in vain to score, but our defense resisted all their efforts, and the ball remained most of the time in Harvard's territory.

The teams lined up as follows:

STEVENS.	POSITIONS.	HARVARD.
Decker	Goal	Sand
Willett	Point	Woods
Corbett	Cover Point	Scott
Maxfield	1st Defense	Leighton
Whitman	2d "	Morrison
Hunter	3d "	F. Outerbridge
Brune	Centre	Horn
Kennedy	3d Attack	Curtis
Christy	2d "	Arnold
Jennings	1st "	Ames
Scott	Outside H	Beecher
Walker	Inside H	Burley

The umpires were S. Outerbridge (H.) and H. Messim '96 (S.), and the referee H. Nelson.

STEVENS *vs.* CORNELL.—On Tuesday, May 14, Stevens played Cornell on grounds soaked with rain, and so slippery as to make sprinting and dodging almost impossible. As some of the regular men were unable to play in good form, owing to the Johns Hopkins game, Sofio, Buckley, L. Hardie, and Hunter were substituted. In this game the Stevens attack played well, and only the fine stopping of Findlay and Cameron prevented their score from being much larger.

The line-up was as follows:

STEVENS.	POSITIONS.	CORNELL.
Sofio	Goal	Findlay
Buckley	Point	Cameron
Corbett (Capt.)	C. Point	Downey (Capt.)
Maxfield	1st Defense	Lyle
Hardie (L.)	2d "	Osborne
Hunter	3d "	Kendall
Jennings	Centre	Swindells
Kennedy (J.)	3d Attack	Frenshaw
Christy	2d "	Strong
Bruckner	1st "	Purman
Whitman	Inside Home	Powell
Scott	Outside Home	Chambers

Referee—J. H. Cuntz, '87.
Umpires—N. Brune, '97; D. Barnum, '95.
Goals—Stevens: Jennings, Maxfield, and Scott.
Cornell: Purman and Chambers.

STEVENS *vs.* HOPKINS.—For some unexplained reason the whole Stevens team appeared in this game to be utterly demoralized. The play of the attack, in particular, was completely devoid of sense. Though they had the ball the greater part of the time, they did nothing but pass it from one to another. When a man did shoot, it was usually from a situation which rendered success almost impossible, although there were other men at the same time, uncovered and in good position. The defense put up a fairly good game, but their play at times showed signs of the general demoralization. No defense can prevent scoring, or win a game, without support from the attack.

The teams lined up as follows:

STEVENS.	POSITIONS.	HOPKINS.
Decker	Goal	Mitchell
Willett	Point	Cone
Corbett	Cover-point	Dawson
Maxfield	1st Defense	Crenshaw
Whitman	2d "	Stevens
Kennedy	3d "	Lupton
Christy	Centre	Janney
Jewell	3d Attack	Shaw
Bruckner	2d "	Kennard
Jennings	1st "	Cameron
Scott	Outside Home	Hodges
Walker	Inside "	Hill

Umpires—Brantz Rozel and W. E. Mallaljeu.
Referee—Henry Penniman.

The ball was faced at about 3.45, and Hopkins started the scoring in very short order. Janney won the face and, dodging Christy and Kennedy, made a hard drive at goal, which was cleverly stopped by Decker ; but, the ball bounding out of line reach, Cameron shinnied it through in about fifteen seconds after play began. It took about ten minutes for Stevens to even up matters, the ball being in the attack most of the time ; but good work by Mitchell and Cone prevented scoring until Bruckner dodged his way into a clear opening and scored from a hard drive. The ball was passed up and down the field a great many times before Scott scored Stevens' second goal, batting it through in a scrimmage. At this part of the game Stevens was outplaying Hopkins at all points, and victory looked certain. Perhaps it was this that, eight minutes later, caused the Stevens centre men to calmly look on while Janney ran way in from the centre of the field and threw Hopkins second goal. The ball should have been stopped easily, but wasn't.

About five minutes before time was called, Cameron received the ball on a pass from Stevens, and shot the ball about a foot over the top of the posts. The goal was allowed, however.

Seven minutes had elapsed during the second half when Janney scored again for Hopkins, after repeated and fruitless efforts on the part of the Stevens attack to pass the ball through Mitchell, Cone, or Dawson. Janney scored again in three minutes. The ball from now on was almost entirely in the Stevens attack, the defense again and again feeding the ball into attack, only to see it passed from one man to another, every one seeming desirous to have every one else shoot the goals, and finally returned by long throws by Cone, or Mitchell. Finally, about ten minutes before time was called, Decker received the ball square in the eye from a hard drive at goal. Willett took his place, and, shortly after, Stevens scored their final goal from a long run and throw by Christy. Hopkins scored immediately after from a shot by Hodges, Willett being out of the goal. Hopkins, 6; Stevens, 3.

The game was played under protest, as Manager Ball had obtained the signature of the Registrar of the University to the

effect that neither Cone nor Crenshaw was a student at the University. As a matter of fact they are both instructors.

STEVENS *vs.* LEHIGH.—The final game of the championship series was played on Saturday, May 25, at the St. George Cricket Grounds. Lehigh displayed winning form, and, from the start, Stevens had little chance of victory. However, considering that they were handicapped by the absence, on account of sickness, of three of last year's champions, Stevens put up a plucky game. Had the entire regular team been able to play, the game would have been made much more interesting, though the final result might not have been changed.

The best playing for Stevens was by Corbett, who excelled anyone on the field, Willett and Scott, while the Lehigh men who excelled the rest were Bastress, in goal, Baldwin, Kip, and Murray.

The teams lined up as follows :

LEHIGH (6).	POSITIONS.	STEVENS (1).
Bastress	Goal	Decker
Fitzgerald	Point	Willett
Murray	Centre Point	Corbett (Capt.)
Dick (Capt.)	1st Defense	Buckley
Enscoe	2d "	Hardie
MacDonald	3d "	Kennedy
Kip	Centre	Jennings
Massey	3d Attack	Jewell
Coleman	2d "	Christy
Bartles	1st "	Scott
Baldwin	Home	Hutchins
Sharrer	Inside Home	Walker

Referee Mr. Kingsley Martin, '92.

Umpires { Messimer, S., '96. / Barber, L., '95.

Goals { Scott (1), Massey (1), Baldwin (3), Sharrer (1), Coleman (1).

FIRST HALF.

The ball was faced at 3.45 P. M., when Stevens carried it quickly toward Lehigh goal. Some snappy work followed in Stevens' attack ; Scott shot well twice in rapid succession, but failed to score, owing to fine stops by Bastress. The ball suddenly went to Lehigh's attack ; Bartles' shot was checked, but Massey scraped it through after just five minutes' play.

On next face-off the playing on both sides was hard, and the ball never remained in either attack for any length of time, traveling always back and forth. Scott dodged well, and shot, but was checked. Then Baldwin got the sphere for a shot ; the ball, being stopped by Decker, fell in a scrimmage from which it was put through, giving Lehigh their second point.

Stevens braced up a little at this point, and made several attempts at goals, all of which failed to score, on account of excellent stops by Bastress. Corbett saved two goals by his clean catching, while Willett stood well by him at times when the goal was hard pressed. After forty minutes Kip rounded the centre, tipped well to Sharrer, who shot while Coleman checked sticks with Decker, making a clean goal five minutes before the end of first half. Before the whistle blew, Jennings and Scott each had another try at the goal. Score, 0—3.

SECOND HALF.

The second half was begun with snap and vigor, and Stevens' attack for a time pressed Lehigh hard. Hardie brought the ball down to Scott, who shot. This shot was stopped, but a minute later he had the ball again and scored a point for Stevens, which latter proved to be our only one. When the ball again got in motion, Jennings and Scott worked well together, one time making what looked very much like a goal, but through lack of system in attack they soon tired, and before ten minutes Baldwin had begun to raise Lehigh's score by a driving, well-placed shot. Score, 1—4. On facing off, Decker twice saved goal from Kip, and Corbett, being body-checked, had his knee hurt. This delayed the game five minutes, but he bravely resumed his position. After Christy made an unsuccessful try at goal, although a good shot, Coleman got the ball, and, by checking sticks, Lehigh scored her fifth goal. Lehigh succeeded in making one more point by a shot from Baldwin's stick, while Stevens' attack played desperately around their goal posts.

FIELD DAY.

The field games this year suffered lamentably from lack of management. A goodly number of contestants appeared in each event, and, if those in charge had shown a proper interest, the games would have been highly successful. As it was, they were run off so slowly that a whole afternoon was spent without completing them, and after being twice postponed the remainder were left unfinished. One record was broken by Jennings, '96, who threw the baseball 349.8 ft. A few days after the games, Bang, '98, who had been unable to attend them, tried for the Institute record for the hammer throw, and broke it with a throw of 79 ft.

Following are the results of the games:

100 yards dash	Jennings, '96. McLain, '98. Frank, '98.	Half mile run	Kidde, '97. McLain, '98. Christy, '97.
Lacrosse ball	Jennings, '96. Weichert, '97. Scott, '98.	Throwing baseball	Pope, '96. Scott, '98. Mathey, '97.
220 yards dash	Mnnings, '96 JecLain, '98. Weichert, '97.		Christy Brune. '97.
Hammer throw	Corbett, '95. Church, '95. Buckley, '98.	Three-legged race	Ray Plum '96.
			Roberts Clark '98.
Standing broad jump	Church, '95. Wood, '97. Frank, '98.	Mile run	Weichert, '97. Handloser, '98 Meister, '97.
Putting shot	Buckley, '98. Wood, '97. Pope, '96.	Half mile walk	Frank, '98. Munby, '97. Lewis, '98.
Running broad jump	Wood, '97. Buckley, '98. Pope, '96.		

SUMMARY.

'95	2 firsts,	1 second	=	13
'96	1 "	2 thirds	=	25
'97	4 "	4 "	=	36
'98	2 "	6 "	=	34

INSTITUTE NOTES.

AT A RECENT MEETING of the Faculty the following resolutions affecting the approval and publication of theses were adopted:

Resolved, That in future all theses, before final approval, must be submitted to all members of the Faculty whose departments include the subjects treated.

Resolved, That the originals of theses shall not be permitted to leave the custody of the Institute. If a thesis be desired for publication, a copy must be obtained.

Resolved, That no thesis will be accepted unless accompanied by the following agreement: The undersigned agrees (or agree) not to publish the above thesis or its substance without the written permission of the president.

PRESIDENT MORTON AND FAMILY departed for Pine Hill, Ulster County, N. Y., shortly after the regular sessions of the Institute closed. They expect to remain at their summer residence, located there, until the Institute reopens.

PROFESSOR KROEH, who is chancellor of the Summer Schools, conducted by the Long Island Chautauqua Assembly Association at Point of Woods, L. I., will have charge of the courses in modern languages during a part of July and August. Professor Webb, assisted by Mr. Ganz, will be in charge of the Department of Mathematics and other exact sciences.

PROFESSOR MAYER is stopping for the summer at his cottage at Maplewood, N. J.

PROFESSOR GEYER sailed for Europe on July 3. He contemplates spending most of the summer in Norway.

PROFESSOR MANNING, having been granted a leave of absence for a year, sailed, with his wife, on the *Ems*, on June 29, for Europe. It is their intention to see various parts of Germany during the summer, and to settle in Berlin for the winter, where Professor Manning will avail himself of the opportunity for advanced study.

AT THE DETROIT MEETING of the American Society of Mechanical Engineers, held June 25th to 28th, Professor Wood presented two papers, one entitled "The Strength of Iron as Affected by Tensile Stress While Hot," and the other, "Analysis of the Tremont Turbine." At the same meeting Professor Jacobus presented a paper on "Tests to Show the Distribution of Moisture in Steam when Flowing in a Horizontal Pipe."

ANNOUNCEMENT HAS BEEN made that on and after June 1, 1895, the co-partnership known as the Union Bridge Company will consist of Messrs. Charles Macdonald and Andrew Onderdonk, civil engineers and constructors of bridges, tunnels, and public works in general.

INSTITUTE PERSONALS.

'75.

A. SORGE, JR., has left Fraser & Chalmers to open an office as Consulting Engineer at 1533 Marquette Building, Chicago, Ill. He purposes making a specialty of the equipment and management of foundries.

'76.

JOSEPH KINGSLAND, JR., having lost his diploma, together with other effects, at a camp in the Sierra Madre Mountains, Mexico, during a prolonged absence North, due to illness, has applied to the faculty for a duplicate diploma, which will be furnished him.

He is not fully recovered from an attack of nervous prostration, and will go this summer to California.

IN describing some tests of ordnance material to be made with the view of demonstrating the resistance of modern armor plate to the heaviest projectiles from high-power guns, the *New York Tribune* of June 24, 1895, refers to Naval Constructor A. W. Stahl as "one of the cleverest experts, who, under the direction of Chief Constructor Hichborn, designed and had constructed at the Norfolk Navy Yard a section of the *Iowa's* belt armor which is to serve as the target in the practical contest between the gun and plate."

'77.

E. A. UEHLING may be consulted on mechanical and metallurgical engineering problems, especially those arising in Modern Blast-Furnace Practice. His address is 214 North Fifth Street, Newark, N. J.

The firm of Uehling, Steinbart & Co., of which he is the head, has just equipped a shop with special tools, at 61 and 63 Mulberry Street, Newark, N. J., for the manufacture of the Pneumatic Pyrometer and other engineering and metallurgical instruments.

'80.

WILLARD P. PARSONS is Chief Engineer of the American Reduction Co., of Brooklyn, N. Y., and is now installing at Pittsburg, Pa., a plant for which he has made the plans and selected the machinery.

'81.

THE FOLLOWING appeared in the *Gas Light Journal*, June 10, 1895:

Messrs. Humphreys and Glasgow inform us that they have just contracted with the Central Gas Light Company, of New York, for the installation of one of their improved water-gas plants, up to a maximum daily producing capacity of one million cubic feet. The apparatus is especially adapted to the handling of heavy oils. Messrs. Humphreys and Glasgow

have also just contracted for the installation of a plant of like capacity for the gas company of Bath, England. Besides the plants already completed by Messrs. Humphreys and Glasgow, they are now under contract (including the two awards above mentioned) to erect plants aggregating a daily capacity of over 13 million cubic feet.

'84.

G. M. SINCLAIR is Secretary and Treasurer of the Technic Electrical Works. The office and factory are at 129 Broad Street, Philadelphia, Pa.

'85.

W. N. STEVENS may be addressed at 29 South Mountain Avenue, Montclair, N. J.

'87.

J. DAY FLACK, formerly Superintendent of Construction, and Engineer with the General Electric Co., has opened an office as Consulting and Constructing Electrical and Mechanical Engineer at 26 Cortlandt Street, room 1010, Havemeyer Building, New York City.

JOSEPH A. MCELROY has been elected to membership in the American Society of Mechanical Engineers.

'88

LEWIS SEARING is secretary and treasurer of The Denver Engineering Works Co., with office at 842 Equitable Building, Denver, Col., and main office and works at Thirtieth and Blake streets.

Messrs. Shepard and Searing, mechanical and electrical engineers of Denver, Col., in conjunction with Mr. William J. Miller, formerly owner of the Miller Forge Company, of Pittsburgh, Pa., have purchased the entire machine shops and foundry of The Overland Machinery Company, of Denver, and have incorporated The Denver Engineering Works Company.

They will manufacture mining, milling, and smelting machinery, and take contracts to design and erect complete mining, steam, and electric plants. They will give especial attention to the electrical transmission of power, as applied to mines and smelters, in which they have had considerable experience.

The officers of the company are: President, William T. Miller; Vice-President, Frank E. Shepard; Secretary and Treasurer, Lewis Searing. The Board of Directors contains some of the best men of Denver: Henry R. Wolcott, President, The Denver Equitable Company; Julian A. Kebler, General Manager The Colorado Fuel and Iron Company; John L. Jerome, Treasurer Overland Cotton Mills; and H. H. Dunham, of Wolcott & Vail.

The Denver Engineering Works Company will soon be in the market to buy iron and steel, machine tools and machinery supplies.

'88-'89.

FRITZ UHLENHAUT, JR., and FREDERICK J. GUBLEMAN have been elected to associate membership in the American Society of Mechanical Engineers.

'91.

ANTHONY KENNEDY is now Chief Engineer of the Hollar Lock Inspection and Guaranty Co., Engineers of Bank Vault Construction, Drexel Building, Philadelphia, Pa.

H. W. SMITH has taken a position as Draughtsman with the Pope Manufacturing Co., Tube Department, Hartford, Conn.

WM. S. ACKERMAN has been promoted from junior to associate membership in the American Society of Mechanical Engineers.

F. M. SANBORN has been elected to junior membership in the American Society of Mechanical Engineers.

'92.

WILLIAM O. LUDLOW has formed a partnership under the firm style of Ludlow & Valentine, Architects, with an office in New York City.

R. L. MARTIN has been appointed Assistant Engineer of the New York and Brooklyn Bridge, Brooklyn, N. Y.

H. D. WHITCOMB, JR., has entered the service of the United Gas Improvement Co., of Philadelphia, as Engineer.

'93.

C. T. BAYLESS, who is assistant to David Leonard Barnes, Consulting Engineer, 1750 Monadnock Building, Chicago, Ill., attended the meeting of the Master Car Builders, held June 11, at Thousand Islands, N. Y. Mr. Bayless is a member of the Western Railway Club.

E. D. LEWIS is Draughtsman for the American Reduction Co., Brooklyn, N. Y.

JAS. V. MACDONALD has been elected to junior membership in the American Society of Mechanical Engineers.

'94.

E. P. BUFFETT, who went to Pittsburg on the staff of the *American Manufacturer and Iron World*, has severed his connection with that journal, and is now Financial Editor of the Pittsburg *Commercial Gazette*, one of Pittsburg's leading dailies.

GEO. WETMORE COLLES, JR., and JOSEPH G. C. COTTIER have been elected as junior members of the American Society of Mechanical Engineers.

FRANK H. COYNE has taken up his residence at 6 Clinton Street, Watertown, N. Y.

C. C. KENYON has been taken into partnership by his father, the firm being D. R. Kenyon & Son, successors to Kenyon Bros., Manufacturers of Woolen Machinery, at Raritan, N. J.

H. D. LAWTON is traveling for Uehling, Steinbart & Co., setting up their pyrometers.

HENRY E. MCGOWAN is with Church & Co., Soda Manufacturers, Trenton, Wayne Co., Mich.

'95.

B. C. BALL is connected with the Ball & Wood Engine Co.

AUSTIN CHURCH is with Church & Co., Manufacturers of Soda, Trenton, Wayne Co., Mich.

WM. H. CORBETT and Edward M. Harrison, Jr., have been elected President and Secretary respectively of their class for a term of ten years.

ALBERT F. GANZ has been engaged by the trustees as Assistant in the Electrical Department of Stevens Institute.

During the summer he is at Point o' Woods, Long Island, assisting Professor Webb with his pupils at the Long Island Chautauqua.

R. E. HALL has been employed by Uehling, Steinbart & Co., to make drawings of their improved form of Pyrometer.

T. E. JEWELL is connected with the Hecker, Jones, Jewell Milling Co., at Brooklyn, N.Y.

FRANK V. LAWRENCE is in the draughting room of the Pope Manufacturing Co., Hartford, Conn.

C. P. PAULDING is Assistant Engineer with the Calumet & Heckla Copper Mining Company, Calumet, Mich.

A. R. WILLIAMS has entered the employ of the American Reduction Co., and is assisting in the equipment of the new plant of that company, at Pittsburg, Pa.

A. E. WOOLSEY has entered the service of the Illinois Steel Co., at South Chicago, Ills.

PERCY ALLAN, P. Arrison, G. E. Bruen, L. Carter, Austin Greenidge, B. H. Jackson, H. Maxfield and Frederick K. Vreeland were employed as Assistant Instructors during the Supplementary Term by the Department of Experimental Mechanics.

BOOK NOTICES.

RECENT PUBLICATIONS.

THE MECHANICAL ENGINEER'S POCKET BOOK. By Wm. Kent, A. M., M. E., Consulting Engineer, Member Amer. Soc'y Mech. Eng'rs, and Amer. Inst. Mining Eng'rs. John Wiley & Sons, 53 E. 10th St., New York City, publishers, 1895.

This is a reference book of rules, tables, data, and formulæ for the use of engineers, mechanics, and students.

The mechanical engineer, especially, will find in this work a vast amount of useful information in convenient form for ready reference and application, and which could not have been obtained, heretofore, except by consulting a great amount of literature, with the expenditure of considerable labor.

Some idea of the scope of the work can be obtained from the general heads under which the subjects treated of have been classified. These are: Mathematics, Materials, Mechanics, Heat, Physical Properties of Gases Heating and Ventilation, Water, Hydraulics, Fuel, Steam, the Steam Boiler, Chimneys, the Steam Engine, Gas, Petroleum and Hot-Air Engines, Locomotives, Shafting, Pulleys, Belting, Gearing, Hoisting, Wire Rope Transmission, Rope Driving, Friction and Lubrication, the Foundry, the Machine Shop, Dynamometers, Ice-Making or Refrigerating Machines, Marine Engineering, Construction of Buildings, Electrical Engineering.

The amount of labor expended in the production of this book has been very extensive, covering a period of about twenty years, during which time the systematic collection of the matter has been diligently pursued. This accumulation of material, which assumed vast proportions, has been carefully sifted and condensed, so that, in the small volume of about 1100 pages, there is placed at the disposal of the engineer an invaluable instrument for the rapid and intelligent prosecution of his work.

This is, we believe, the only American pocket book that is distinctively devoted to mechanical engineering in the sense in which Trautwine's Pocket Book is devoted to civil engineering. Price, $5.00.

ELEMENTARY ALGEBRA. By H. S. Hall and S. R. Knight. Revised and Enlarged for the Use of American Schools by F. L. Sevenoak, Assistant Principal of the Stevens School.

This revision of Hall and Knight's Elementary Algebra was undertaken for the purpose of adapting it to meet the requirements of a text-book for the preparation of students desiring to enter colleges and technical schools.

The revisor has succeeded admirably in accomplishing his purpose, and in its enlarged and improved form this text-book will rank with any other now published upon the same subject.

One of the most valuable features of the book is the large number of carefully selected examples given in each chapter, and the collection of miscellaneous examples at the end of the book.

ACCESSIONS TO THE INSTITUTE LIBRARY, JAN. 1, 1895, TO JULY 1, 1895.

Books Purchased.

Specifications and Drawings, U. S. Patent Office. May, 1893; July, 1893; August, 1893; September, 1893.
Treatise on Integral and Differential Calculus. By B. Williamson.
Comptes Rendus. Vols. 116, 117.
Annual Report Commissioner of Patents for 1893.
The Mechanical Engineer's Pocket-Book. By Wm. Kent.
Fortschritte der Elektrotecknick, 1893. By Dr. Karl Strecker.
Oils, Fats, and Waxes. By Benedikt and Lewkorintsch.
The Filtration of Public Water Supplies. By Allen Hazen.
Chemical Technology. Vol. II. Lighting. By Groves and Thorpe.

Books Contributed.

By President Morton. *Transactions American Society of Mechanical Engineers.* Vol. 15. Two copies.
By Prof. Denton. *Transactions American Society Civil Engineers (1894).*
By Prof. Denton. *Transactions American Institute Electrical Engineers (1894).*
By Prof. Winchell. *The Geological and Natural History Survey of Minnesota (1894).* By N. H. Winchell.
By Prof. John Smock. *Annual Report State Geologist, N. J. (1893).* By J. C. Smock.
By Smithsonian Institute. *Smithsonian Geographical Tables.* By R. S. Woodward.
By Smithsonian Institute. *A Journey Through Mongolia and Tibet.* By W. W. Rockhill.
By Smithsonian Institute. *A Bibliography of Acito-Acetic Esters.* By P. H. Seymour.
By Smithsonian Institute. *The Varieties of Human Species.* By Giuseppe Sergi.
By Smithsonian Institute. *Chinook Texts.* By Franz Boas.
By Smithsonian Institute. *The Sionan Tribes of the East.* By J. Mooney.
By Smithsonian Institute. *Archæologic Investigations in James and Potomac Valleys.* By G. Fawke.
By U. S. Treasury Department. *Annual Report Secretary U. S. Treasury for 1892 and 1893.*

By U. S. Treasury Department. *Annual Report U. S. Lighthouse Board, 1894.*

By U. S. War Department. *Annual Report Chief of Engineers U. S. Army, 1894.*

By the Chief of Ordnance. *Annual Report Chief of Ordnance U. S. Army, 1894.*

By U. S. Commissioner of Labor. *The Slums of Baltimore, Chicago, New York and Philadelphia.* By C. D. Wright.

By U. S. Bureau of Education. *History of Higher Education in Rhode Island.* By W. H. Folman.

By G. C. Maynard. *Patent Centennial Celebration (1891).*

By Hon. G. B. Fielder. *Eleventh Census U. S. (Insurance).*

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CONSULTING ENGINEER,
PASSAIC, NEW JERSEY.

Author "The Mechanical Engineer's Pocket-Book."

A. FABER DU FAUR, JR., 132 NASSAU STREET, NEW YORK.
Solicitor of American and Foreign Patents and Expert in Patent Causes.

(STEVENS '84.)

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ASTOR, LENOX AND
TILDEN FOUNDATIONS.

STEVENS INDICATOR.

VOL. XII. OCTOBER, 1895. No. 4

TEST OF A 240 HORSE-POWER BABCOCK & WILCOX BOILER WITH THREE DIFFERENT COALS, FOR THE DETERMINATION OF ECONOMY.

BY ST. GEORGE M. ANDERSON, '94; EDMUND J. BURKE, '94.

This boiler is situated in the American Sugar Refinery, Jersey City, and is the end boiler of a battery of six of the same type.

The three kinds of coal used in these tests were the ones used at the sugar refinery for general running. They were as follows: soft coal, pea and dust, and rice or fine buckwheat.

These tests were to be supplemented by a like run with the same boiler under the same conditions, but fired with the Coxe Mechanical Stoker, instead of by hand, in order that a comparison might be made of the economy of the two systems of firing boilers. For that reason the tests were made very thoroughly, and great care was taken with the readings, weighings and analyses.

The tests were of forty-eight hours' duration, and readings were taken and analyses of the chimney gases made every half-hour. Determinations of the moisture of the coal fed to the boiler were made every three or four hours.

These tests were under the supervision of Mr. George Dinkel, Chief Engineer of the sugar refinery, to whom we are indebted for permission to make the tests, as well as for his kindness and the assistance he gave us in the work.

The test of the stoker was to have been included in our

work, but time and circumstances prevented us from undertaking it. This test was made later by Mr. Dinkel.

DESCRIPTION OF BOILER.

This boiler is a Babcock & Wilcox boiler, and was erected in 1887, and at that time was their latest style of boiler, the general form of which is shown in Fig. I. It consists of fourteen sections, nine tubes to a section, with one circulating tube to each section. These tubes are eighteen feet in length, with a diameter of four inches.

There are two steam drums in this boiler, each thirty-six inches in diameter and eighteen feet seven inches long, and to each drum there is attached a four-inch safety-valve. The surface of the grate is fifty-six square feet, and the heating surface 2,758 square feet. The height of the chimney is one hundred feet.

This boiler, when bricked in, occupies a space twenty-three feet five inches long, eleven feet four inches wide, and fourteen feet high to the steam flange in the steam drum.

The draught was forced, being produced by a Sturtevant blower and fed to the double battery of boilers. It was regulated for each boiler by a separate damper.

The steam passed from the boiler into a steam main, into which all the rest of the boilers fed. As ordinarily run, the boilers were fed with water heated by the economizers in the flue; in these tests, however, the boiler tested was cut off from the others and fed with water at the temperature of the supply main.

In the battery of six, of which the boiler tested was one, the chimney gases were led to one chimney by separate flues.

The boiler was thoroughly overhauled and cleaned before the preliminary test of thirty-six hours was run. It was also well steamed out before each of the regular tests.

STANDARDIZATION OF THE INSTRUMENTS USED.

The instruments used were standardized, and the corrections noted before the running of the test. The high-temperature thermometers, used for taking the temperatures in the

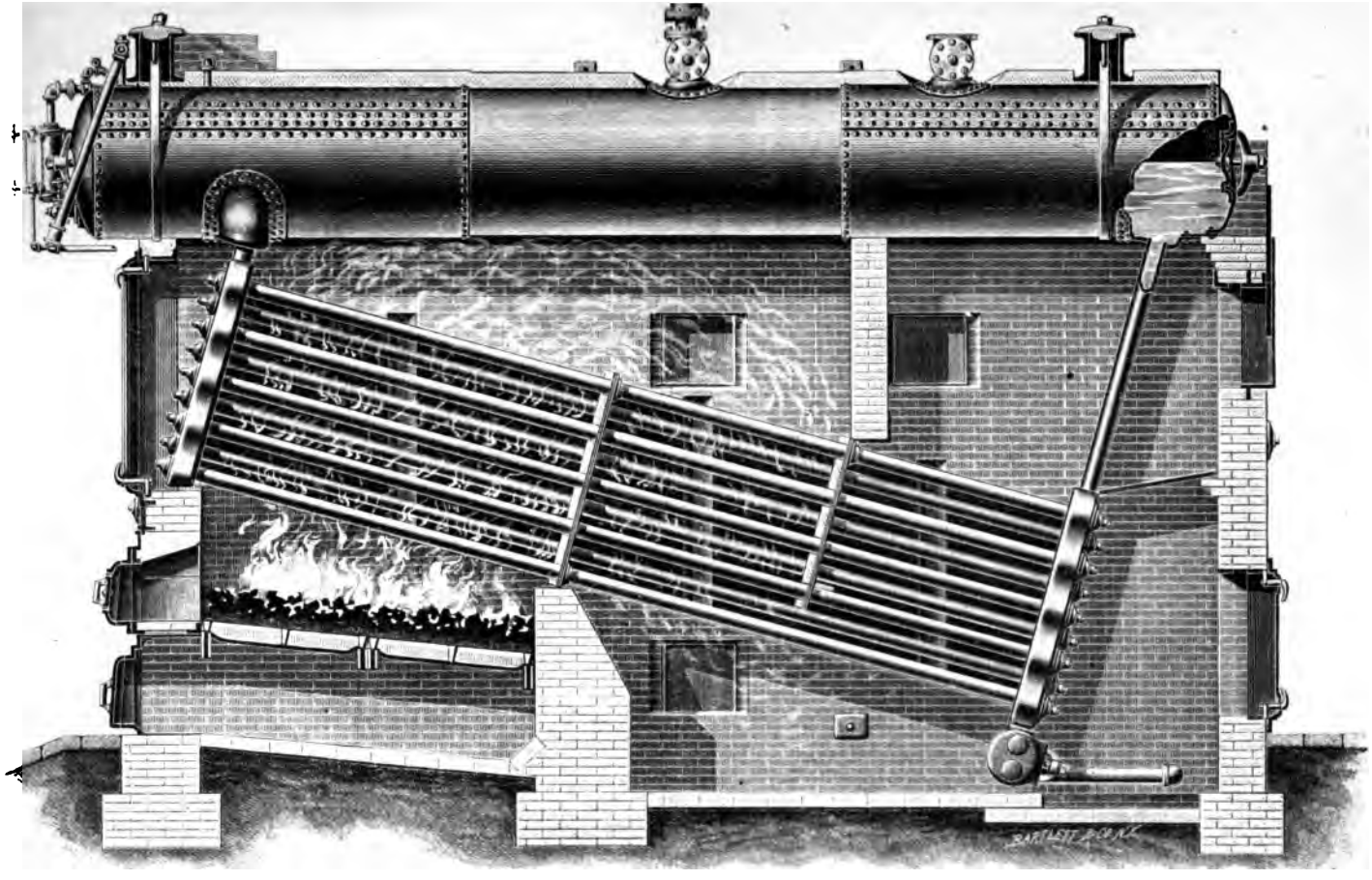


FIG. 1.

steam pipe and calorimeter, were first standardized at the boiling-point of water at atmospheric pressure, and afterwards in mercury wells at the temperatures at which they were to be used.

In a like manner, the pressure gauges and pyrometers were standardized for the pressures and temperatures at which they were to be used. The following are the corrections for each. In order to obtain a better average correction for the three high-temperature thermometers, since the temperatures which they were to indicate were about the same, an average was taken of the correction of each for the different temperatures at which they were standardized:

	CORRECTION.
Thermometer used for temperature of steam.....	+3.6°
" " " " " feed water..	−0.66°
" " " " " boiler room.	−2.0°
" " " taking temperature of blast.	0.0°

At the pressures used throughout the three tests, the correction for the steam-pressure gauges was two pounds, to be subtracted from the readings of each gauge.

The two pyrometers were standardized by their maker, and corrections were made accordingly.

The Barrus Calorimeter was standardized and found to allow sixty pounds of steam per hour to pass the orifice, at seventy pounds gauge-pressure.

The scales used for weighing the water and coal were thoroughly cleaned, leveled, and standardized before the test.

MANNER OF CONDUCTING TESTS.

At the beginning of each test the fires were drawn and new ones started with a weighed amount of wood. Up to the time of drawing the fires and starting the test, the boilers were fired sufficiently hard to keep the steam pressure up to the point at which it was to be maintained throughout the run.

The following readings were taken every half-hour:

The height of the water in the water glass was measured in inches. The temperature of the steam in the steam pipe and the temperature of the steam after passing the orifice of the

Barrus calorimeter. The temperature of the chimney gases by two pyrometers, called No. 1 and No. 2, in different parts of the flue. The temperature of the boiler-room, and the barometer. The temperature of the blast and feed-water. The strength of the blast, in inches of water, was taken from U tubes, called Nos. 1, 2, 3 and 4, which were connected with perforated iron pipes running across the ash-pit, six inches below the bottom of the grate-bars, and about seventeen inches apart. Two pressure-gauges were used, one a Bristol recording gauge and the other an ordinary steam gauge, reading to pounds, so that one would serve as a check upon the other.

The instruments were placed as follows: The room thermometer and barometer were placed at a sufficient distance away from the boiler so that they would not be affected by the heat from the boiler. The feed-water thermometer was placed in a well sunk in the supply pipe just above the feed tanks. The blast thermometer was suspended in the blast flue. The steam-pipe thermometers were placed in a mercury well sunk in the elbow of the outlet steam pipe directly above the boiler. The calorimeter was attached to the vertical outlet pipe about three feet above the boiler, and was allowed to run constantly during the tests. On the preliminary run the calorimeter was tried several times with the separator, but as the separator was found to be unnecessary, it was removed before the final run, the steam being found to be uniformly dry. That the steam was dry was also checked by observing the quality of steam which issued from a drip placed at the bottom of the horizontal pipe leading from the boiler. The steam which issued from this jet was transparent for a distance of several inches below the pipe.

The water was fed to the boiler by a separate pump, which drew from two large rectangular iron tanks alternately, each weighing, when full, about 2,200 pounds, and about 650 pounds when empty. The tank was first weighed when full, then the pump was set to work and the water pumped out of the tank to about three inches of the bottom, when the valve was closed and the pump started on the other tank, which had been filled and weighed in the meantime. The almost empty tank was then weighed, and the difference between the weight of the tank full and of the tank empty gave the amount of the water

pumped into the boiler from this tank. This tank was then filled, weighed again, and the same operation repeated. One man attended to the water alone, in order that there should be no opportunity for a mistake of any kind in the amount of water supplied to the boiler. Each tank stood on separate platform scales.

The coal was weighed in an iron barrow holding about 300 pounds, the weight of the empty barrow being taken each time, so as to prevent any error arising from gain or loss of weight in the barrow. As the barrow was filled, samples of coal were taken out from each barrowful, so as to obtain a fair sample of the coal for analysis. These samples were placed in a keg, and every three hours an average sample was taken from the keg, placed in a canvas bag, and sent up to the refinery laboratory to have the moisture determined. The sample was then labeled and placed aside, to have still another sample selected from it for analysis.

The three ashes—clinker ash from above the grate bars, ash from under the grate, and ash collected from the back connections of the boiler—were treated in a similar manner. Great care was taken that no water should be thrown on the ash before it was weighed and samples were taken.

The method of determining the moisture was as follows: Take a platinum crucible, weigh in it 1.5 grammes of the powdered coal, transfer to a drying oven and heat to 103° C. for fifteen minutes; cool in a dessicator and weigh. Loss is moisture. The results of the moisture tests were as follows:

TEST OF MOISTURE IN SOFT COAL.

1st sample,	April	2,	1894,	3.30	P.M.,	Moisture	2.10	per cent.
2d	"	"	"	9.00	"	"	1.63	"
3d	"	"	"	12.00	"	"	2.27	"
4th	"	"	3,	3.00	A.M.,	"	2.25	"
5th	"	"	"	7.00	"	"	2.74	"
6th	"	"	"	10.00	"	"	2.74	"
7th	"	"	"	1.00	P.M.,	"	2.46	"
8th	"	"	"	4.00	"	"	1.40	"
9th	"	"	"	7.00	"	"	2.50	"
10th	"	"	"	10.00	"	"	2.23	"

TEST OF MOISTURE IN SOFT COAL.

(Continued.)

11th	sample,	April	4,	1894,	1.00	A.M.,	Moisture	2.25	per cent.
12th	"	"	"		4.00	"	"	2.81	"
13th	"	"	"		7.00	"	"	4.90	"
14th	"	"	"		10.00	"	"	2.38	"
15th	"	"	"		1.00	P.M.,	"	2.19	"

MOISTURE IN CLINKER OF SOFT COAL.

1st	sample,	April	3,	1894,	when weighed,	0.06	per cent.
2d	"	"	4,	"	"	0.00	"

MOISTURE IN ASHES.

Ash from ash-pit,	1st sample,	0.0334	"
Back Ash,	"	1.4	"

TEST OF MOISTURE IN PEA-AND-DUST COAL.

1st	sample	April	5,	1894,	1.00	P.M.;	Moisture	2.66	per cent.
2d	"	"	"		5.00	"	"	2.34	"
3d	"	"	"		9.00	"	"	3.16	"
4th	"	"	6,		1.00	A.M.,	"	2.97	"
5th	"	"	"		3.40	"	"	2.84	"
6th	"	"	"		9.00	"	"	2.30	"
7th	"	"	"		12.00	"	"	5.32	"
8th	"	"	"		3.00	P.M.,	"	4.65	"
9th	"	"	"		9.30	"	"	3.47	"
10th	"	"	7,		2.30	A.M.,	"	2.06	"

MOISTURE IN CLINKER OF PEA AND DUST.

1st	sample,	April	6.	1894,	when weighed,	0.013	per cent.
2d	"	"	7,	"	"	0.00	"

TEST OF MOISTURE IN RICE OR FINE BUCKWHEAT COAL.

1st	sample,	April	9,	1894,	11.45	A.M.,	Moisture	4.72	per cent.
2d	"	"	"		2.00	P.M.,	"	3.69	"
3d	"	"	"		9.00	"	"	4.80	"
4th	"	"	10,		1.00	A.M.,	"	4.56	"
5th	"	"	"		4.40	"	"	6.11	"
6th	"	"	"		9.00	"	"	7.53	"

TEST OF MOISTURE IN RICE OR FINE BUCKWHEAT COAL
(Continued.)

7th	sample,	April	10,	1894,	2.00 P.M.,	Moisture	5.92	per cen.
8th	"	"	"		3.45 "	"	6.66	"
9th	"	"	"		11.00 "	"	6.41	"
10th	"	"	11,		2.00 A.M.,	"	7.62	"
11th	"	"	"		5.20 "	"	6.82	"

MOISTURE IN CLINKER.

1st	sample,	April	10,	1894,	9.00 A.M.,	.000	per cent.
2d	"	"	"		11.00 P.M.,	0.03	"

The samples were obtained as follows: When the keg was full the coal was spread out on the floor and thoroughly mixed; then it was placed in a circular pile and quartered. Two opposite quarters were thrown away and the remaining two were mixed together. The process was repeated until the sample used for the analysis was obtained.

COAL AND ASH ANALYSES.

At the conclusion of the tests the coals and ashes were taken to the Stevens Institute and analyzed according to the scheme of Prof. Thos. B. Stillman, as follows:

"Take a platinum crucible (capacity about 25 c. c.) weigh in it 1.5 grammes of the powdered coal. Transfer to a drying oven and heat to 103° C. for fifteen minutes; cool in a desiccator and weigh. Loss is moisture. The crucible containing the dried coal is now heated over a Bunsen burner for three and one-half minutes, then over the blast-lamp for three and one-half minutes more, care being taken that the cover of the crucible fits closely. Cool in the desiccator. Loss in weight equals volatile and combustible matter plus one-half of the sulphur. The crucible and contents are now heated over a Bunsen burner (lid of crucible removed) until all carbonaceous matter is consumed. Replace cover of crucible, cool in desiccator and weigh. Loss in weight is fixed carbon plus one-half of the sulphur."

The following are the results of the different analyses:*

*The results of the ash analyses are an average of those obtained by the authors and those obtained in the laboratory of the sugar house.

ANALYSES OF COAL AND ASHES.

SOFT COAL.

Moisture	0.7136	per cent.
Volatile and combustible matter + ½ sulphur	24.0348	"
Carbon + ½ sulphur	70.5572	"
Ash	4.6940	"
Total	99.9996	per cent.

CARBON IN ASH OF SOFT COAL.

Clinker ash	23.6	per cent.	carbon
Ash from ash-pit	36.4	"	"
Back ash	49.3	"	"

HARD COAL (PEA AND DUST).

Moisture	0.61232	per cent.
Volatile and combustible matter + ½ sulphur	9.6409	"
Carbon + ½ sulphur	80.9667	"
Ash	8.77995	"
Total	99.99987	per cent.

CARBON IN ASH OF PEA-AND-DUST COAL.

Clinker ash	10.7	per cent.	carbon
Ash from ash-pit	36.7	"	"
Back ash	45.2	"	"

RICE OR FINE BUCKWHEAT COAL.

Moisture	2.73782	per cent.
olatile and combustible matter + ½ sulphur	7.7571	"
Carbon + ½ Sulphur	69.3225	"
Ash	20.1824	"
Total	99.99982	per cent.

CARBON IN ASH OF BUCKWHEAT COAL.

Clinker ash	25.5	per cent.	carbon.
Ash from ash-pit	48.4	"	"
Back ash	50.5	"	"

It will be noticed in the determinations of the per cent. of carbon in the ash taken from the ash-pit, that the amount in the third test for buckwheat coal was excessive. This excess may be accounted for in several ways. The coal was very fine and could fall through the grate bars in greater quantity than the larger sizes; the fires had to be worked and cleaned constantly, thus affording greater opportunities for small particles of the unburnt coal to fall through the grate.

ANALYSIS OF CHIMNEY GASES.

The instrument used for the analysis of these gases was the Elliott apparatus, as described in "Phillips' Engineering Chemistry," page 121. The samples of the gas were taken about fifteen minutes after firing, so as to allow the coal time to burn thoroughly, and in each case seven samples were run through the apparatus, so as to drive out all the air, Fifteen analyses were made during each test.

The method of operating this apparatus is as follows: Samples of the gas are drawn into the graduated tube and the reading taken. The gas is then drawn over into the other tube, which we will call the secondary tube, and treated with potassium hydrate (KHO), which absorbs all of the CO_2. This should be allowed to stand for ten or fifteen minutes to allow all of the CO_2 to be absorbed. The gas is thus drawn back into the graduated tube and the reading taken. The difference between the readings divided by the original volume of the gas give the per cent. of CO_2 present. The gas is then drawn back into the secondary tube and treated with a solution of pyrogallic acid, which absorbs the oxygen present in the gas. The gas should be allowed to remain in contact with the potassium hydrate and pyrogallic acid for at least ten minutes, to obtain the entire absorption of the oxygen. The gas is then drawn back into the graduated tube and a reading taken. The difference between this reading and the former reading, divided by the original volume of the gas, gives the per cent. of oxygen present. The secondary tube must then be thoroughly washed out and have the air driven out of it by water. The gas is again drawn into the secondary tube and treated with cuprous chloride, which absorbs all of the CO pres-

ent. The gas must then be drawn back into the graduated tube, but no reading yet taken, as acid fumes are present. The secondary tube must again be well washed out and the air driven out as before. The gas is then drawn back into the secondary tube and treated with potassium hydrate, which absorbs the hydrochloric acid fumes generated by the cuprous chloride. Allow to stand for ten minutes. The gas is drawn into the graduated tube and a reading taken. The difference between this and the former reading, divided by the original volume of the gas taken, gives the per cent. of CO present in the gas. The remainder of the gas is supposed to be nitrogen. There may be some hydrocarbons present, but if there are, they are present in such minute quantities as to make their determination almost an impossibility.

After taking a sample of a gas it should be allowed to stand for at least twenty minutes before the first reading is taken, so as to allow it to come to the temperature of the room and a constant volume.

The gas was collected from a perforated three-quarter-inch iron pipe running the whole depth of the flue, the pipe being allowed to remain in the flue all the time. Water, free from air bubbles, was used in the Elliott apparatus and was allowed to stand long enough to be at the temperature of the room.

The following are the analyses of the different tests. The damper was open, and the ash-pit doors were closed throughout:

ANALYSES OF FLUE GASES.

TEST WITH SOFT COAL.

Time.	Per ct. CO_2.	Per ct. O.	Per ct. CO.	Per ct. N.
4.30 P. M.....	11.6	3.2	4.1	81.1
8.15 "	13.0	6.4	1.0	79.6
11.45 "	10.7	8.6	1.1	79.6
4.00 A. M.....	10.0	6.2	1.5	82.3
7.30 "	13.4	3.2	2.6	80.8
11.00 "	4.3	8.2	2.0	85.5
1.00 P. M.....	3.5	10.0	1.7	84.8
2.30 "	9.9	9.57	0.8	20.27
4.45 "	6.5	11.8	Air got in.	
9.30 "	10.4	8.5	0.2	80.9

ANALYSES OF FLUE GASES.

TEST WITH SOFT COAL.

(Continued.)

Time.	Per ct. CO_2.	Per ct. O.	Per ct. CO.	Per ct. N.
1.30 A. M.....	11.1	5.0	0.8	83.1
4.30 "	9.0	7.2	0.8	83.0
7.30 "	7.4	5.1	1.2	86.3
11.00 "	7.5	10.5	0.4	81.6
1.00 P. M.....	8.0	11.0	0.1	80.9

TEST WITH HARD COAL.

Time.	Per ct. CO_2.	Per ct. O.	Per ct. CO.	Per ct. N.
12.00 M.....	9.4	8.5	3.7	78.4
3.30 P. M.....	10.8	5.6	1.4	82.2
6.00 "	9.29	10.5	0.3	79.91
9.30 "	10.1	8.8	0.44	80.66
1.30 A. M.....	7.7	6.6	0.8	84.9
3.30 "	7.2	11.0	0.7	81.1
7.30 "	6.0	8.8	1.7	83.5
12.00 M.....	7.3	10.1	0.7	81.9
2.30 P. M.....	7.1	6.3	0.66	85.94
5.00 "	11.6	6.58	0.94	80.88
7.00 "	9.72	4.4	1.7	84.18
11.00 "	10.08	8.3	0.76	80.14
2.15 A. M.....	10.1	7.3	0.42	82.10
6.00 "	8.7	Air got in.		

TEST WITH BUCKWHEAT COAL.

Time.	Per ct. CO_2.	Per ct. O.	Per ct. CO.	Per ct. N.
11.45 A. M.....	6.69	6.25	1.67	85.39
3.30 P. M.....	9.03	6.46	2.9	81.61
6.30 "	7.68	7.38	1.9	83.04
10.00 "	15.8	2.23	0.82	81.15
12.00 M.....	9.97	5.98	1.33	82.72
4.00 A. M.....	6.4	8.4	0.81	84.39
7 00 "	10.05	8.9	0.69	80.36
9.20 "	8.02	8.8	0.55	82.65
11.45 "	11.3	8.65	0.52	79.53
3.30 P. M.....	10.51	6.52	0.93	82.04
6.10 "	13.91	6.5	0.00	80.59

TEST WITH BUCKWHEAT COAL.

(Continued.)

Time.	Per ct. CO_2.	Per ct. O.	Per ct. CO.	Per ct. N.
10.00 "	12.22	6.85	0.45	80.42
12.30 A. M.....	7.78	8.35	0.68	83.19
4.00 "	9.04	7.44	1.03	82.49
7.00 "	10.80	8.87	0.22	80.11

In the foregoing tables of the analyses of the chimney gases the per cent. of CO is quite small, showing that the combustion of the gases was good. The per cent. of O present showed an excess of air, which may be accounted for by the fact that the normal condition of the damper was open, and that the blast used was strong, the boilers being driven, so that the horse-power developed was beyond the rating of the boilers.

Table I. is a comparative one of the three tests:

TABLE I.

AVERAGE DATA AND RESULTS OF TESTS.

1. Date of Tests....April 2, 5 and 9, 1894.
2. Type of boiler....Babcock & Wilcox, rated at 240 H. P.
3. End boiler in a battery of six, American Sugar Refinery, Jersey City, N. J.
4. Fuel....Three grades of coal.
5. Distribution of power....The boiler fed directly into a steam main, from which steam was taken for engines, pumps and sugar machinery.
6. How draught was produced....Sturtevant blower.
7. How coal was measured....In an iron wheelbarrow on platform scales.
8. How water was measured....Weighed.
9. Condition of boiler when test commenced....Before the preliminary run the boiler had been thoroughly overhauled and cleaned. It was steamed out between each two tests.
10. Average condition of damper and ash-pit doors....The damper was open, and the ash-pit door closed.
11. Grate surface, square feet....56.
12. Total heating surface, square feet....2,758.
13. Ratio of heating to grate surfaces..... 49.2.
14. Distance traveled in feet by the products of combustion from grate to chimneys....171.
15. Height of chimney, feet....100.
16. Safety valves....Number in use, 2; diam. of each, inches....4.

		First Test. Soft Coal. Apr. 2, 1894.	Second Test. Hard Coal (Pea & Dust) Apr. 5, 1894.	Third Test. Buckwheat Coal. Apr. 9, 1894.
17.	Time that wood was lighted and test commenced	3.30 P. M.	10.00 A. M.	9.15 A. M.
18.	Length of the test in hours	48	48	48
19.	Steam pressure at start, lbs. per sq. in., above atmosphere	69.25	67.5	63.5
20.	Height of water in water glass at start, inches	5.5	4.75	6.0
21.	Total weight of water fed to the boiler, lbs.	577,414	411,608	453,185
22.	Average thickness of fire, inches	12	10	12
23.	Average draught, in inches, of water	0.3864	0.465	0.945
24.	Average steam pressure, lbs. per sq. in., above atmosphere	71	68.72	69.36
25.	Average height of water in water glass, inches	3.79	4.51	4.10
26.	Average temperature of feed water, degrees Fahr.	48.07	50.88	49.32
27.	Average temperature of chimney gases, degrees Fahr.	653.	613.	597.
28.	Average temperature of steam in boiler, degrees Fahr.	311.7	311.2	311.20
29.	Average temperature of fire room, degrees Fahr.	58.15	62.81	63.13
30.	Average barometric pressure, inches of mercury	30.10	30.03	30.05
31.	Composition of chimney gases by volume — Oxygen	7.63	7.9	7.17
	Carbonic acid	8.42	8.98	9.93
	Carbonic oxide	1.3	1.09	0.9766
	Nitrogen	82.65	82.03	81.9234
32.	Composition of fuel as given by analysis — Carbon = $\frac{1}{2}$ Sul.	70.5572	80.9667	69.3225
	Oxy. & Hydrogen + $\frac{1}{2}$ S.	24.0348	9.6409	7.7571
	Ash	4.604	8.77999	20.1824
	Moisture	0.7136	0.61232	2.73782
		99.9996	99.99991	99.999982
33.	Barrus Calorimeter — Temperature of superheated steam at exit, degrees Fahr., as registered by a mercury thermometer	272.26	271.10	273.26
34.	Total wood used, lbs.	708	361	630
	Equivalent in coal, 1 lb. of wood = 0.4 lb. coal	283.22	144.4	252
35.	Total dry coal used, lbs.	74,070	56,559	70,405
	Total wet coal used, as it came from the coal pile, lbs.	75,893	58,233	74,725
36.	Refuse	6,023	7,472	14,678
37.	Total fuel used, lbs., dry coal + .4 weight of wood,	74,353	56,703	70,657
	Total combustible, lbs.	68,330	49,231	55,979

TABLE 1.—(CONTINUED).

	First Test. Soft Coal. Apr. 2, 1894.	Second Test. Hard Coal (Pea & Dust) Apr. 5, 1894.	Third Test. Buckwheat Coal. Apr. 9, 1894.
38. Actual per cent. of ash	8.10	13.17	20.77
39. Rate of combustion, lbs. per sq. ft. of grate per hour	27.66	21.09	26.286
39. Rate of combustion, lbs. per sq. ft., of heating surface per hour	0.56	0.428	0.53
40. Quality of steam. average per cent. priming per lb. of steam*	Dry.	Dry.	Dry.
41. Weight of water which would have been fed if the temperature of feed water were 212° Fahr. and steam evaporated at actual boiler pressure, lbs	672,212	478,064	527,051
42. Weight of water which would have been fed if the temperature of feed water were 212° Fahr. and steam were evaporated at atmospheric pressure, lbs	694,825	493,864	544,556
43. Evaporation, in lbs., per lb. of dry fuel — From temp. of feed water and at actual steam pressure	7.77	7.26	6.41
43. Evaporation, in lbs., per lb. of dry fuel — Equivalent from and at 212° Fahr	9.34	8.71	7.71
44. Evaporation, in lbs., per lb. of combustible. — From temp. of feed water and at actual steam pressure	8.45	8.36	8.10
44. Evaporation, in lbs., per lb. of combustible. — Equivalent from and at 212° Fahr	10.17	10.03	9.73
45. Evaporation, in lbs. per hour, per sq. ft. of heating surface — From temp. of feed water and at actual steam pressure	4.36	3.11	3.42
45. Evaporation, in lbs. per hour, per sq. ft. of heating surface — Equivalent from and at 212° Fahr	5.25	3.73	4.11
46. Horse-power according to standard recommended by the American Society of Mechanical Engineers, *i. e.*, 34½ lbs. of water evaporated from and at 212° Fahr., per hour	419.58	298.23	328.84
47. Square feet of heating surface required for each horse-power	6.57	9.25	8.39
48. Air supplied per lb. of fuel — Pounds	14.05	16.24	12.95
48. Air supplied per lb. of fuel — Volume at temperature of 32° Fahr., cu. ft.	174.10	201.21	160.55

*Radiation of calorimeter allowed for. Possible error of determination two-fifths of one per cent.

METHOD OF CALCULATING RESULTS.

The articles numbered from 1 to 36 are taken directly from data obtained during the tests.

37. The total fuel used equals the total dry coal, as given in article 35, plus the equivalent, in coal, of the wood used in starting the fires, article 34. Total combustible equals the total fuel, 37, minus the ash.

38. The actual per cent. of ash equals the ash × 100 ÷ the total fuel, 37.

39. The rate of combustion per square foot of grate per hour equals the total fuel, 37, divided by the length of the test in hours × the grate area in square feet.

40. The per cent. of priming was calculated from the formula.

Per cent. of priming = 100 $(1-x)$.

$$x = \frac{H_2 + 0.48\,(T_2 - 212) - (H_1 - h_1)}{h_1}$$

in which

H = total heat.
h = latent heat.
x = fraction of pound of water evaporated.
T_1 = temperature of steam before passing orifice in Barrus calorimeter.
T_2 = temperature of steam after passing orifice in Barrus calorimeter.

41. Article 41 was calculated by the following formula: Weight of water which would have been fed if the temperature of the feed water was 212° Fahr., and steam evaporated at actual boiler pressure = Actual water evaporated × $(H - t_f) \div (H - 212)$. Where t_f is the temperature of the feed water and H represents the total heat above 0° Fahr. per pound of saturated steam at the average boiler pressure.

42. Article 42 was calculated by the following formula: Weight of water that would be evaporated during time of test from and at 212° Fahr. = Actual water evaporated × $(H - t_f) \div 966$, where t_f and H represent the same quantities as in the previous article.

Articles 43 to 45 are obtained by dividing the total quantities by the total weight of the fuel, etc.

46. To obtain article 46, the evaporation per hour from and at 212° Fahr. is obtained by dividing the total result given in article 42 by the length of the test in hours. This result divided by 34.5, gives the horse power of the boiler.

47. Divide the total heating surface by the horse power.

48. The following method was used to obtain article 48 : The pounds of air required to burn one pound of carbon =

$$\frac{3}{3}\left(\frac{2\,(CO_2 + O) + CO}{CO_2 + CO}\right) \div 0.23,$$

in which O, CO_2, and CO are the per cents. by volume of the several constituents of the chimney gases.

$$\text{The pounds of air per pound of coal} = \left\{\begin{matrix}\text{Pounds of air per}\\ \text{pound of carbon}\end{matrix}\right\} \times \begin{matrix}\text{Per cent. of carbon}\\ \text{in the coal.}\end{matrix}$$

To reduce to volume at temperature of 32° Fahr., the following formula was used :

$$V_0 = 12.387 \times \text{pounds of air per pound of coal.}$$

COMPARATIVE COST OF POWER WITH THE THREE KINDS OF FUEL.

It can be seen, from the preceding tabulated record of the three tests, that the conditions were the same in each. Therefore, a comparison may well be made of the results obtained in the three runs, in order to see which coal gave the best economy.

The cost of these three coals, delivered in front of the boiler, are as follows :

Pea and dust	$ 1.54 per ton.
Fine buckwheat	1.465 " "
Soft coal	2.60 " "

In the soft-coal test there were used 75,893 pounds of wet coal in forty-eight hours, or 37.95 tons of 2,000 pounds each at $2.60 per ton. The cost of the coal was, therefore, $98.67. The boiler generated 419.58 H. P. Therefore, each horse power cost $\frac{98.67}{419.58 \times 48} = \$0.0049$ per hour.

Of the pea-and-dust coal there were used 58,233 pounds of wet coal, or 29.12 tons of 2,000 pounds each, at $1.54 per ton. The total cost of the coal was, therefore, $44.84. The boiler generated 298.23 H. P. Therefore, each horse power cost $\frac{44.84}{298.23 \times 48} =$ $0.00313 per hour.

In the buckwheat-coal test there were used 74,725 pounds of wet coal, or 37.36 tons of 2,000 pounds each at $1.465 per ton. The total cost of the coal was, therefore, $54.73. The boiler generated 328.84 H. P. Therefore, each horse power cost $\frac{54.73}{328.84 \times 48} =$ $0.00347 per hour.

The reasons for making the calculations and comparisons on the basis of wet coal is that by "wet coal" is meant the coal as it came from the coal pile, and as it was fed to the boiler.

We have concluded from the above calculations that the hard coal (pea and dust) is the most economical for this boiler, as fired during these tests.

The total dry coal used in the soft-coal test was 740,70 pounds, or 37.035 tons of 2,000 pounds each, at $2.60 per ton. The cost of the coal was, therefore, $96.29. This being divided, as before, by the number of horse power developed, and by the length of the test in hours, gives the cost per horse power as follows: $\frac{\$96.29}{20140} =$ $0.00478 per hour.

In the hard-coal (pea and dust) test, the total dry coal was 56,559 pounds, or 28.28 tons of 2,000 pounds each, at $1.54 per ton. The total cost of the coal was, therefore, $43.55, and the cost per horse power $\frac{43.55}{14315} =$ $0.00304 per hour.

The total dry coal used in the last test was 70,405 pounds, or 35.2 tons of 2,000 pounds each, at $1.465 per ton. The total cost the coal was, therefore, $51.57, and the cost per horse power was $\frac{51.57}{15784.3} =$ $0.00327 per hour.

From these calculations we have concluded that the hard coal (pea and dust) is the most economical, when reckoned for the dry coal as well as for the wet.

If the carbon wasted in the ash-pit were saved, the comparative cost per horse power for dry coal would be as follows:

Soft coal, cost per H. P., $\frac{95.55}{20140} = \$0.0047$.

Hard coal (pea and dust), cost, per H. P. = $0.0029.

Buckwheat coal, cost per H. P. = $0.0031.

From a comparison of these figures the hard coal (pea and dust) still has the advantage for economy.

The latter calculations were made by taking the weight of the ash-pit ashes, multiplying by the percentage of carbon, thus finding the weight of unburnt coal lost, finding the cost of this unburnt coal for each of the different coals at their respective prices and subtracting from the total cost of each; then dividing as above.

AN INTERESTING WELL EXPERIENCE.

BY H. DE B. PARSONS, '84, M. E.

The following interesting experience in the supposed contamination of a well water was experienced in my practice; and, thinking that the result might be of service to others, I take pleasure in stating the facts.

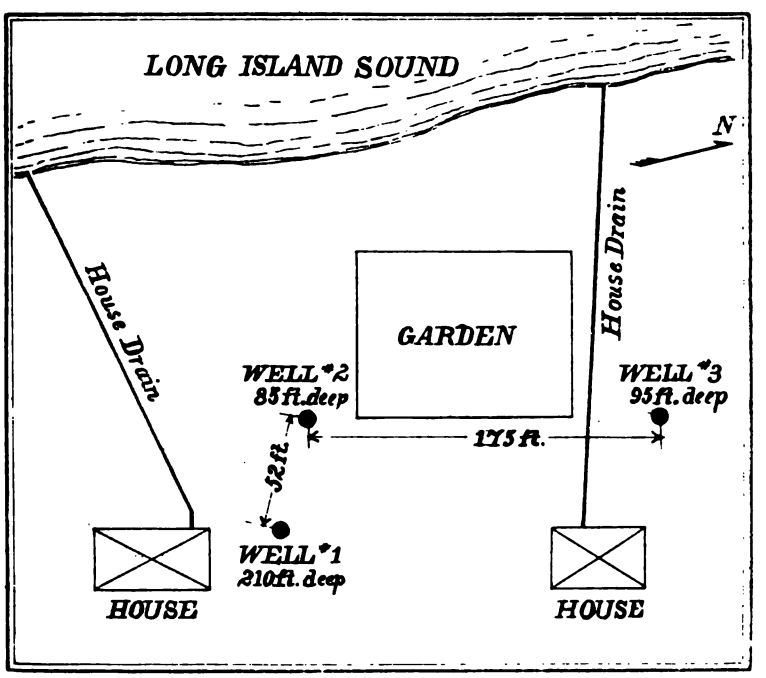
In order to secure a supply of good, potable water for domestic use at a private residence situated near Rye, Westchester County, N. Y., it was decided to drive a six-inch well. In the immediate neighborhood a number of such wells had been driven, and the supply of water from each varied from about five gallons to thirty-five gallons per minute, the average depth of these wells being between sixty and one hundred feet.

The ground in the neighborhood of the place is occupied by private residences, although there is considerable property still in an unimproved state. All the houses in the immediate vicinity of the proposed well drain into an arm of Long Island Sound, through closed drain-pipes, some of which are built of cast-iron pipes with lead joints, and others with glazed tile-pipe, with cement joints.

The proposed well was located as shown in the accompanying map, and marked No. 1. As will be seen, there was a small garden in the immediate vicinity, and, with that exception, all the rest of the property was in lawn. The only fertilizer used was a little bone-dust put on certain bare spots on this lawn. There was no stable in the immediate vicinity of the well, the nearest being about 275 feet away, situated directly on the bank of the Sound. The next stable was situated over 300 feet away, in the opposite direction. Both the private houses shown on the map are small country homes, accommodating small families. The soil-pipes from these houses are shown on the map, and both of them are new. These soil-pipes were laid in trenches, most of them being in rock cuts, so that,

had there been any leak, which is not probable, the moisture would have followed the pipe through the trench into the Sound. The natural rock in this vicinity is Westchester gneiss, standing at nearly a vertical angle, so that the outcropping runs practically north and south.

The contract for driving the well was let to Conlin Bros., and well No. 1, consisting of a six-inch hole, was started and carried to a depth of eighty-five feet. Rock was encountered



at three and one-half feet below the surface, and a steel casing was put in place for that depth, the lower end being cemented to the rock. For the full depth of the well the character of the rock changed but very little. Water appeared in the well at a depth of forty feet, and rose to within fifteen feet of the surface. As only a small quantity of water was obtained when the well was tested, it was decided to carry it to a greater depth, and it was finally extended to two hundred and ten feet.

No great variation in the rock was experienced, and at that depth no in crease in the water supply was obtained, although the water still maintained its level at about fifteen feet from the surface.

It was then decided to torpedo the well, with the hope of increasing the flow. About fifty pounds of nitro-glycerine were exploded in three charges, one charge being put at the bottom of the well, another about one hundred and fifty feet from the surface, and the third about sixty feet from the surface. The supply was not, however, materially increased by these explosions.

This well was then abandoned, and another made, as shown on the map, marked Well No. 2. This second well was carried to a depth of eighty-five feet, and the character of the rock was the same as that found in Well No. 1. The surface of the rock was found about four feet below the surface of the ground, and that part of the well, like the former, was lined with a steel casing, cemented to the rock. As this well gave a little greater supply than Well No. 1, amounting to about one gallon a minute, and as that supply was sufficient for drinking purposes further extensions were not undertaken.

The well marked No. 3 on the map is a well of the same character as those just described, but was bored about five years previously. This well is six inches in diameter by ninety-five feet deep, and gives a supply of about twelve gallons per minute. The surface of the ground slopes away toward the north, so that the top of Well No. 3 is a few feet lower than the top of Well No. 1, and the water in all the wells stands at the same level. This level is about ten feet above high-water mark, and is not affected by the rise and fall of the tide.

Well No. 2 was equipped with a small hand-pump, and water was pumped about ten minutes each day for four days, when a sample was taken and analyzed by Mr. Alfred L. Beebe, Ph.B. The result of this analysis is given in the accompanying table under Analysis 1, and the sample was condemned on account of the presence of nitrites, the high percentage of albuminoid ammonia, and nitrogen in nitrates and organic and volatile matter, indicating the filtration of surface water of bad quality, apparently contaminated with sewage.

	Analysis 1.	Analysis 2.	Analysis 3.
Appearance	Turbid	Clear	Very slightly turbid
Color	Dark yellow brown	Bluish	L't yellowish brown
Odor (heated to 100° F.)	Strong, marshy	Earthy	Earthy
Chlorine in chlorides	1.7500	1.4350	1.6800
Equiv. to sodium chloride	2.8900	2.3700	2.7740
Phosphates	None	None	None
Nitrogen in nitrites	0.0002	0.0010	None
Nitrogen in nitrates	0.1972	0.1625	0.0408
Free ammonia	0.0005	0.0015	0.0005
Albuminoid ammonia	0.0100	0.0030	0.0010
Total nitrogen	0.2061	0.1664	0.0420
Hardness, equiv. to (before boiling)	5.4200	5.1200	5.1200
Carbonate of lime (after boiling)	5.4200	5.1200	5.1200
Organic and vol. (loss on ignition)	5.0000	5.0000	2.0000
Mineral matter (non-volatile)	8.1000	8.0000	8.7000
Total solids (by evaporation)	13.1000	13.0000	10.7000

The quantities are stated in parts by weight in 100,000.

As it did not appear possible that any sewage could contaminate the well, daily pumping was continued for over two months, when a second sample was given to Mr. Beebe for analysis. The result of this analysis is given in under Analysis 2. While the appearance and color of the sample was undoubtedly greatly improved, and the amount of albuminoid ammonia much reduced, there was a decided increase in the nitrogen in the nitrites and in the free ammonia. Judging from the analysis it would appear that the organic matter of animal origin present was undergoing a greater degree of oxidation; but the analysis appeared to show that the well was still strongly contaminated by sewage.

As Well No. 3 had been used continuously for five years, and as no sickness had been caused thereby, and as, from the nature of the ground, it did not seem possible that sewage contamination could be present, even from distant sources, it was decided to make an analysis from Well No. 3. The result of this analysis is given under Analysis 3.

Comparing these analyses, it appears that the waters of the three wells are of the same general character, and evidently come from the same sources of supply. There was a marked

difference, however, in the quantity of nitrogen present, and in the free and albuminoid ammonias. The reduction in the quantity of total solids by evaporation was probably due to the longer period of use, which had thoroughly cleared the well. It, therefore, seemed that the apparent contamination of Well No. 2 was entirely due to the effects of the dynamite exploded in Well No. 1, and for domestic purposes it was just as good as that obtained from Well No. 3. The slight improvement between the first and second analyses of Well No. 2 was probably due to the continued pumping, which also sucked into it from Well No. 1 certain quantities of nitrogen, which showed in the increase of the nitrates, as well as in the increased amount of free ammonia.

It will probably be many months before the apparent contamination will be exhausted.

THE MAXIMUM POSSIBLE EFFICIENCY OF GALVANIC BATTERIES.*

BY PRESIDENT HENRY MORTON, PH.D.

To discuss this question in an exact and numerical manner, it will be necessary to indicate with precision what class of batteries are referred to, and I will therefore say at the outset that I refer only to those, which long experience has proved to be the most efficient in supplying large currents, excluding those of the Leclanche type, which yield only feeble currents.

In all the batteries to which I now refer there are the following common features:

1st. The energy is derived from the combination of zinc with dilute sulphuric acid.

2d. The supply of oxygen required for this combination is obtained directly or ultimately by the decomposition of water or some other compound in aqueous solution.

In other words, the batteries here considered are the Smee, the Daniels, the Grove or Bunsen, and the various forms in which chromic acid is the oxygen-supplying substance, which may be indicated by the name of Poggendorff, who was the first to suggest its use.

This being premised, we can begin with the following general statement of principles:

1st. The source of energy being the reaction between the metallic zinc and the dilute acid, its amount can be expressed in *British thermal units* as follows: Oxidation of zinc, 2340 B.T.U.; solution of oxide in dilute sulphuric acid, 666 B. T. U.; or in all 3006 B. T. U., as the total energy developed by the union of the zinc and acid.

No arrangement of parts or employment of one material or another in other parts of the cell, or for other parts of the reaction can *add* anything to this; but, on the other hand, there must always be more or less subtracted from it, to meet the demands of the reaction, to say nothing of internal resistance of the solutions, local action, etc.

In order that the zinc should combine with the acid, the hydrogen which it displaces or whose place it takes, must be

* From *Cassier's Magazine*.

driven out or otherwise taken care of, and this will demand an expenditure of energy, greater or less, but always considerable.

For example, in the Smee battery the hydrogen is simply driven out in bubbles of gas. To do this requires 2106 B. T. U. for each pound of zinc dissolved. Taking this from 3006 leaves only 900 B. T. U. as *even possibly available* from each pound of zinc consumed in a Smee battery, to say nothing of losses coming from local action, resistance, etc.

This difficulty was realized at an early period, and was met by supplying oxygen to take up the hydrogen, and so avoid the great loss involved in expelling it.

To supply this oxygen various substances have been used, but the only ones of practical importance are sulphate of copper, nitric acid, and chromic acid.

But even with these more or less energy must be expended in decomposing them and securing their oxygen. The energies involved are as follows:

	B. T. U.
Sulphate of copper, Daniels' battery	1587
Nitric acid, Grove's or Bunsen's	283.6
Chromic acid, Poggendorff's	178.5

If these various amounts are subtracted from the maximum thermal value of the zinc-in-sulphuric-acid-combination, we will have for the several batteries:

	B. T. U.
Smee battery, as before	900
Daniels' battery	1419
Grove's or Bunsen's battery	2722.4
Poggendorff. (Chromic acid)	2827.5

These figures represent the absolute maxima of energy which a pound of zinc could develop in these forms of battery, excluding all losses from resistance, etc.

To get a practical view of these results, however, it will be necessary to reduce them to equivalent *foot-pounds of work*, and to horse-power *rates of doing work*.

Now, Joule has shown that each B. T. U. equals 772 foot-pounds, and this means that the energy expressed by the heat which will raise one pound of water one degree Fahrenheit (this is the B. T. U.) would lift one pound 772 feet, or 772^2 pounds one foot.

If, then, we multiply the figures given above, we shall have the various energies expressed in foot-pounds of work.

In other words, a pound of zinc consumed in these various

batteries would develop the following numbers of foot-pounds, all losses from resistance, etc. being excluded:

	Foot-pounds.
Smee's battery	694,800
Daniel's "	1,095,468
Grove's "	2,101,694
Poggendorff's	2,182,820

If in each of these batteries one pound of zinc was consumed in a minute, then the above numbers of foot-pounds would represent the work developed in a minute in each case, and to turn this into horse-power, we should divide each number by 33,000, because a horse-power is a rate of doing work of 33,000 foot-pounds each minute. This will give us the horse-power represented by the solution of one pound of zinc *each minute* in each battery.

Smee's battery	21.05	H. P.	for one	minute.
Daniel's "	33.19	"	"	"
Grove's "	63.66	"	"	"
Poggendorff's	68.57	"	"	"

Such a rate of consuming zinc as a pound a minute, would of course require an immense galvanic battery and indeed it is usual to express the consumption of fuels generally in pounds per *hour*. To get the horse-power due to the consumption of zinc at the rate of a pound an *hour*, we divide the above figures by 60 (there being 60 minutes in an hour) and this gives the horse-power developed by a pound of zinc consumed during an hour as follows:

Smee's battery	.35	or about	$\frac{1}{3}$	H. P.
Daniel's	.55	" "	$\frac{1}{2}$	"
Grove's	1.06	" "	1	"
Poggendorff's	1.14	" "	$1\frac{1}{7}$	"

This shows that in the best forms of battery an allowance of one horse-power for each pound of zinc consumed per hour, would be a liberal one, if something is allowed, as it must be, for the resistance, local action, etc.

It may, however, be asked: If such an improvement has been made as above shown, from the Smee battery giving $\frac{1}{3}$ to the Poggendorff yielding $1\frac{1}{7}$ horse-power, may we not expect further improvements as great in amount?

To this I answer certainly not in this class of batteries.

The entire energy of the reaction between the zinc and dilute acid is 3006 B. T. U. This would represent 2,320,632. foot-pounds or 70.62 horse-power for one minute, or 1.17—say $1\frac{1}{6}$

horse-power for one hour, and this would be an ***absolute maximum*** which could never be reached, far less exceeded.

Of course, if we could use some other and more efficient reaction than that between zinc and sulphuric acid, some gain might be secured; but nothing of that sort has ever been accomplished, nor, from what is known of the combining or thermal equivalents of the available elements, is much to be expected in that line. At all events, we may well accept this as a certain fact, that in any known form of galvanic battery the round figure of a pound of zinc per horse-power per hour, is an ***outside figure*** for efficiency, and when one asserts that more than this has been secured there is certainly some mistake or fraud.

THE CHEMICAL AND PHYSICAL EXAMINATION OF PAPER.

BY PROF. THOMAS B. STILLMAN.

(Continued from p. 287.)

5. *Determination of the weight per square metre.*

It is best to use, when possible, five different pieces of the paper (from different packages or rolls), each piece about 1 square decimetre.

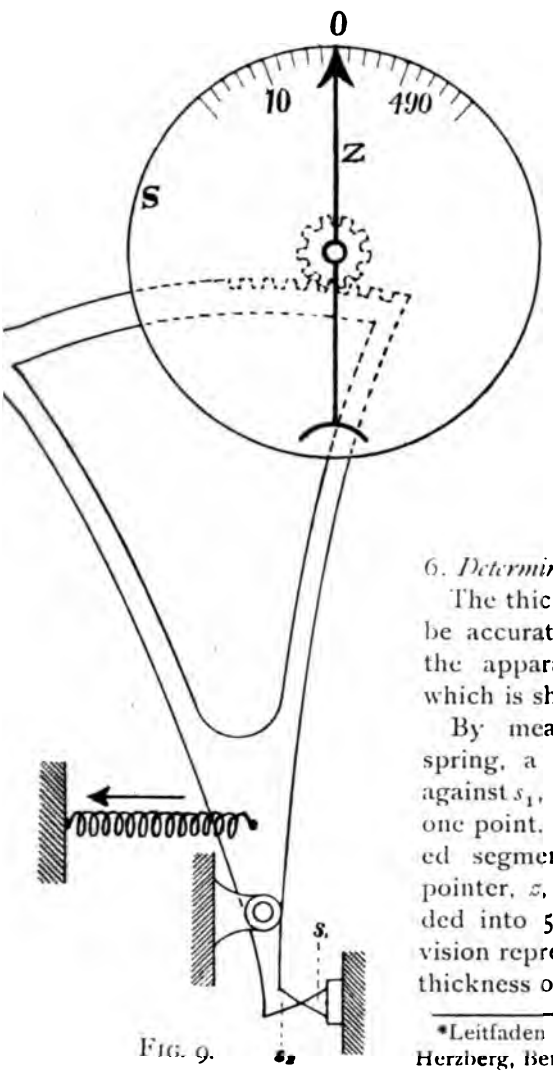


FIG. 9.

These are placed in a drying oven and exposed to a temperature of 105° C. until the weight becomes constant. The weight of the five pieces, multiplied by 20, gives the weight of 1 square metre of paper.*

6. *Determination of the thickness.*

The thickness of paper can be accurately determined by the apparatus, a sketch of which is shown in Fig. 9.

By means of a delicate spring, a lever, s_2, is held against s_1, touching s_1 only at one point. S_2 carries a toothed segment, which moves a pointer, z, along an arc divided into 500 parts. One division represents 0.002 mm. of thickness of the paper tested.

*Leitfaden fur Papier-prufung, W. Herzberg, Berlin, 1888.

7. Determination of breaking strength.

By the strength of a paper is understood the measurement of the resistance it offers to breaking or tearing strains. This resistance is always greater in the direction of the length of the web of paper, as it is made on the paper-machine, than across the web. On the other hand, the amount of elongation, which is measured while determining the breaking strain, is greater in the direction across the web than parallel to it.* The tensile strength of the sheet, both across and parallel to the web, is determined separately, and the average values recorded. To ascertain the direction corresponding to the motion of the paper machine, in any sample of machine-made paper, a circular piece is cut and placed on the surface of water, when it will be observed to roll up. The diameter of the disk where it is not curved indicates the direction of the length of the web. The strips of paper used for ascertaining the tensile strength and elongation are cut to the following size: 180 mm. long by 15 mm. broad. Five strips, at least, are taken from different sheets and representing the length and across the web, in order to obtain good average values. These strips must be carefully cut: the edges should be smooth and run parallel. Cutting tools are provided for this purpose, consisting of an iron ruler and plates of zinc or glass.

Before determining the tensile strength and elongation, careful attention must be paid to the amount of moisture in the atmosphere. The breaking strain of paper decreases with increase of moisture in the air, while under the same influence the percentage amount of elongation increases. The humidity of the atmosphere is very important when testing animal-sized paper and should on no account be overlooked. Indeed, the breaking strain values can only be compared when they are obtained in atmospheres of equal humidity. The percentage atmospheric humidity chosen is 65, because it is much easier to add moisture to the atmosphere than abstract moisture from it. The former is done by boiling water in the room. The instrument in use for measuring the humidity of the air is the Koppe-Sauss-

* Verhandlung des Vereins zur Beförderung des Gewerbefleisses in Preussen; 1885.

ure's air hygrometer. Before testing, the strips of paper are placed in the room for at least two hours. The principal machines in use for determining the breaking strength of paper are:

The *Hartig-Rensch*, the *Wendler* and the *Chopper Apparatus;* a description of the Wendler being given herewith.

This machine is used for ascertaining the strength and elasticity of paper. It consists in the main of four parts; Fig. 10.

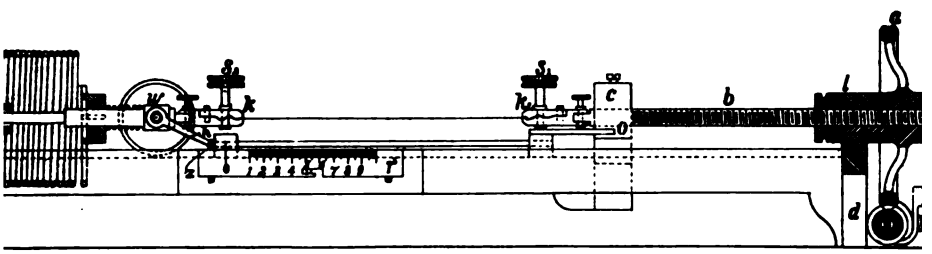


FIG. 10.

1. The driver.
2. Apparatus for mounting.
3. Apparatus for transmission of power.
4. Apparatus for measuring force and stretch.

The driving is produced by a hand-wheel, *a*. The hub of this wheel turns in the bearing *l*, which is cast in one piece with the bed, *d*. The screw, *b*, is led through this hub, which is hollow, and is fastened to the slide *c*, and through its agency the slide is moved. The hand-wheel,is equipped with a bolt-nut, consisting of the shell *p*, and two split nuts, which may be opened or closed by means of a worm, according as the motion of the slide is to be produced by the hand alone or through the agency of the wheel.

The mounting apparatus consists of two clamps k, k_1, the the first fastened to the carriage *w*, the second to the slide *c*. Between the jaws of these clamps the paper to be tested is stretched. The jaws of these clamps are normal to the axis of stress, wave-shaped, and are lined with leather, in order to prevent the slipping of the strip in the clamps. The jaws are pressed together by means of the screws s_1, s_2.

The transmission of the force is done in this, as in most of this class of machines, by means of a spiral spring, those of

Wendler's apparatus possessing respectively a maximum force of 9 and 20 kgs. The spring is held at one end by means of the shell *i*, which is fastened to the bed *d*, at the other by the carriage *w*. The rack *f*, is fastened to the carriage *w*, and passes through the shell *i*. Fastened to the bed by means of screws are the catches *g*, which work in the teeth of the rack, and which, as soon as the paper tears, prevent the spring from flying back.

The measurement of the force is performed as follows:

By means of the lever *h* the carriage pushes the pointer *d* before it, which travels on the graduated bar, *r*. The pointer has a zero mark from which, after the breaking of the paper, the breaking strength is read in terms of kilograms.

The measurement of the elasticity is done by reading the movement of the pointer in the opposite direction along the measuring rod *o*, graduated according to the percentages on a strip 180 mm. in length. After the breaking of the paper, the stretch can be read directly in per cent.

In order to test paper with this apparatus, one adjusts the force measuring rod, by raising the catches, setting the spring in oscillation, allowing it to come to rest and then carefully sliding the pointer down until it touches the lever. Observe whether the zero of the pointer agrees with that of the measuring rod. If this is not the case, the latter is moved until both coincide. The spring is now fastened by means of a screw *t*, and the sled is moved until the zero marks of both sled and stretch-measuring rod coincide. Take a piece of the paper to be tested, previously cut to standard size, clamp it in, loosen the screw *t*, drop the catches and begin the experiment, giving the wheel a slow and uniform motion. After breaking the paper, read off the loading as well as the stretch, relieve the spring by holding the carriage still with one hand, loosening the catches with the other and allowing the spring slowly to slide back into place.

In order to insert a new spring, take the carriage and by means of it push the spring in the direction of the screw *t*, turn the spring through 90° and take out the carriage and the rack.

In conducting the experiments, strips 180 mm. long and 15

mm. broad should be used, and not less than five cut from each direction.

In order to render the result independent of the cross section, use is made of the example of Profs. Reuleaux and Hartig. Using for the measure of strength of paper the "tearing length," which is the length of a strip of paper of any breadth and thickness, which, if hung up by one end, would break in consequence of its own weight.

Let x = unknown tearing length.

G = wt. of the torn strip (in 0.18 mm. length), in grams.

K = no. of kilos necessary to tear strip.

$$\text{then } \frac{0.18}{G} = \frac{x}{K}, \quad \text{or} \quad x = \frac{0.18}{G} K.*$$

For testing materials which require more power to break han paper, as for instance cardboard, Schopper has constructed a more powerful apparatus, which has a maximum force of 150 kgs. As the apparatus is built on the same fundamental principles as the "Wendler," a description here is needless.

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"The Chemistry of Paper-Making," R. B. Griffin & A. D. Little, 1894.

"Mittheilungen aus den Königlichen technischen Versuchsanstalten zu Berlin," 1891, 1892, 1893.

* Paper-Zeitung, 1881.

E. F. C. DAVIS.

LATE PRESIDENT OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

The Council of the American Society of Mechanical Engineers entered upon its records and those of the Society the following minute expressive of the respect and regard felt by its members for their late President, Mr. E. F. C. Davis, whose death from an accident was so sudden and untimely.

"The formal mould of memorial resolutions in which a corporate body ordinarily records its action, seems inadequate for a proper voicing of the spirit which pervades the council in the presence of the death of one whom its members had known so well and whom they had learned to admire and love. His wise and mature judgment, his business and professional knowledge, his conservative yet energetic counsel and his courteous consideration for others had made him one from whose administration of the Society's affairs the highest hopes had been entertained.

"Although, with such grief the stranger intermeddleth not, yet the council would presume to express their heartfelt sympathy with those nearest and dearest to Mr. Davis upon whom this blow has so crushingly fallen."

RAILROADS AND CANALS.

(Continued from page 307.)

No. 4.

Extract of a letter from Robert R. Livingston, Esq

ALBANY, March 11, 1812.

Dear Sir:

I did not till yesterday receive yours of the 25th of February; where it has loitered on the road I am at a loss to say. I had before read your very ingenious propositions as to the railway communication. I fear, however, on mature reflection, that they will be liable to serious objections, and ultimately more expensive than a canal. They must be double, so as to prevent the danger of two such heavy bodies meeting. The walls on which they are placed must at least be four feet below the surface, and three above, and must be clamped with iron, and even then would hardly sustain so heavy a weight as you propose moving at the rate of four miles an hour on wheels. As to wood, it would not last a week; they must be covered with iron, and that, too, very thick and strong. The means of stopping these heavy carriages without a great shock, and of preventing them from running upon each other (for there would be many on the road at once), would be very difficult. In case of accidental stops, or the necessary stops to take wood and water, etc., many accidents would happen. The carriage of condensing water would be very troublesome. Upon the whole, I fear the expense would be much greater than that of canals, without being so convenient.

No. 5.

Answer to Robert R. Livingston's Objections.

NEW YORK, March 16, 1812.

Dear Sir:

Yours of the 11th inst. I have just now received, and as you probably will not remain in Albany until this letter reaches that

place, I have directed it to Mr. G. Morris, that the Commissioners may be duly apprised of the answers I shall give to your objections against the proposed railways.

"I fear," you say, "the expense would be much greater than that of canals." I have in my memoir stated the expense of the railways at one-fourth of that of a canal; and, for the reasons I shall now assign, I am now convinced the difference of expense between them will be much greater, if wood only is used.

The Commissioners have estimated the expense of excavating a canal fifteen yards wide, and three feet deep, "at $1,500,000, drawn through a favorable soil lying conveniently, without the opposition of rocks or other impediments. Many of these, however, must be expected, and perhaps double that sum."

Thus, then, the cost of the canal merely is estimated by the Commissioners at $3,000,000. "If the locks be put at $1,500,000, it is the lowest rate that can prudently be supposed. It would, indeed, be safer to set them at two millions."

Not one shilling of this aggregate sum of five millions would be required in the erection of railways. "There will still remain for aqueducts, embankments and mounds a considerable expenditure," and "it is believed that one million of dollars would provide for everything of this sort." Nearly one-half of this sum would be required in constructing a mound over the Cayuga Lake one hundred and thirty feet high, sixty feet wide at top, with a base of one hundred and ninety feet at bottom, whereas the railways would not require a mound at this place of one-tenth part of this magnitude, and so in proportion throughout the whole distance. We will, however, estimate the necessary embankments, mounds, etc. (aqueducts none would be wanted) at half a million of dollars. There now remains, then, the cost of the railways to be calculated. I shall, in the first instance, suppose the whole to be constructed of wood. Calculating timber at New York price of twelve and a half cents per cubic foot, four rails, then, of six inches wide, by twelve inches deep, would make two cubic feet, or twenty-five cents a foot running measure, equal to $1,320 per mile. The posts or pillars, say eight feet long, at twenty-five cents apiece,

twelve feet apart, four rows would be one dollar for every twelve feet, or $440 per mile. Digging holes, setting posts, braces, and carpenter work, $740. Total, $2,500 per mile, or $750,000 for the whole distance of three hundred miles. This sum of $750,000, added to $500,000 estimated for embankments, mounds, etc., makes an aggregate sum of $1,250,000 for the whole expense of the railways. And should they even require to be totally renewed once in every ten years, still a capital of $1,500,000, or double the sum of $750,000, would be more than adequate to the purpose.

For the reasons already assigned in the memoir, these wooden ways must be much more durable than the plank on a bridge; and I must confess I do not perceive on what grounds you found your assertion, when you say that they would not last a week.

But were we to admit the absolute necessity, in the first instance, of shoeing these railways with iron, the whole expense of them would fall far short of the cost of a canal. For this purpose I should prefer plate iron of about an eighth of an inch thick. Such plates, I presume, might be procured for twelve and a half cents per pound, at which rate the shoeing four rails would cost somewhat less than $4,000 per mile, or $1,200,000 for the whole distance. Should, however, cast iron be preferred plates of an inch thick would cost for the whole distance about $3,000,000.

These plates, provided they remained unaffected by frost, would last an age, and, by protecting the wooden ways from the effects of the weather, will render them also very durable.

One manifest advantage would, however, attend the adoption of these railways; we would be able to count the cost of the undertaking with sufficient accuracy before the business was commenced, whereas the cost of a canal is, in a great measure conjectural, and may, at all events, be estimated at more than double the sum calculated upon by the Commissioners.

But, after all, I must beg leave to refer once more to the very judicious observations of the Commissioners on the subject of expense. "No supposable expense can bear an undue proportion to the value of the work. Thus, were it (by giving a loose to fancy) extended to fifty millions of dollars, even

that enormous sum does not exceed half the value of what, in all human probability, and at no distant period, will annually be carried along the canal. The more proper question, perhaps, is, in what *time* can it be effected?"

Were I not thoroughly convinced of the many superior advantages of the proposed railways over canals, the mere saving of expense would not alone induce me to press their adoption. But were railways to cost fifty millions of dollars, whilst a canal could be completed for five, yet if there is any truth in my calculations, still the railways would ultimately prove the cheapest. Two-thirds of the expense of transportation would be saved by substituting railways in the place of a canal. The period is not far distant, then, when the annual amount of this saving would be equal to legal interest on a capital of fifty millions, even should the calculation be founded on the supposition that the increase of population in the western country should in future be in no greater ratio than what it has been for the last ten years. But the increase of population will most assuredly be in a much greater ratio, more especially should these railways be speedily completed.

When you say that a thick stone wall, "clamped with iron, could hardly sustain so heavy a weight, moving at the rate of four miles an hour on wheels," you appear to have formed an erroneous idea of the distribution of the weight. One hundred tons placed on four wheels would indeed be a very "heavy weight," but it is not contemplated to put more than one ton on four wheels, or certainly not more than two tons, which would be only five hundred, or, at most, one thousand pounds on each wheel. So moderate a weight could surely have little or no tendency to crush down the ways, and the quicker the passage of the wheels over, then the less would be this tendency.

But I am surprised that you should consider canals as being more convenient than the proposed railways. I must own that I am not able to perceive that canals, in this respect, have in any one particular a preference over them; but, on the contrary, they have in many respects a preference over canals.

In the first place, as there are no locks to pass through, and separate ways for the up and down transit, there can never be any interruptions or detentions. And everyone, whether he is

induced to travel either by business or pleasure, can calculate with certainty and precision when he will arrive at the end of his journey; I may, indeed, say, with almost absolute certainty; for it must be recollected that the simplicity and equable motion of the machinery, and the perfect uniformity of the work to be performed, precludes almost entirely the possibility of derangement. Wind and tide, rough and smooth water, light or darkness, would have no influence whatever over steam carriages moving on these ways.

It cannot be denied, then, that these circumstances must render the travel on these railways *very convenient.* But it is not the certainty alone, but the celerity and dispatch of this mode of traveling which gives it so decided a preference to navigating on a canal, and, indeed, to every other mode of conveyance. The farmer who carries his produce to market will, by means of this mode of conveyance, save three days out of four. And by means of it, also, the traveler will in one day perform more than a week's journey on a canal.

But "many accidents would happen by carriages running against each other, in case of accidental or necessary stops.' There are easy and obvious modes of effectually guarding against all accidents of this sort. In the first place, deposits of wood and water must be formed every ten or twelve miles; and each suit of carriages must make no regular halt except at those places. As to accidental stops, these, for the reasons assigned above, will very rarely or never happen. The stopping-places must, of course, be always on level ground. And it must be an invariable and established rule, that *all* the carriages which stop at one time and place be firmly connected to each other.

Whilst these regulations are strictly observed, no accidents of this sort can ever happen. The conductor of each suit of carriages is precisely acquainted with the position of every stopping-place, and governs himself accordingly. He takes care to bring to in time, so as not to run against other carriages; and should it be necessary (although I am inclined to think it will not) means might readily be taken to bring to more expeditiously. For the accommodation of carriages for carrying passengers it will be very practicable and easy to contrive, at each of these stopping-places, a mode of turning out on the

adjoining ways, so as to admit of their passing the carriages for the transport of heavy articles.

"But the means of stopping these heavy carriages without a great shock would be very difficult." It is very surprising that you should apprehend the least difficulty about a thing so easy to effect. On stopping the engine, the friction of the wheels, turning on their axis, will gradually retard the motion of the whole suit of carriages (the friction operating uniformly at the axis of each wheel), till at length they will all, almost imperceptibly, became stationary, without the possibility of producing anything like a *shock*.

"The carriage of condensing water would be very troublesome." I am persuaded you would never have advanced this objection, had you adverted to the circumstance of my stating expressly in the memoir that the engine was to be wrought by the elasticity of the steam merely.

I have now fully, and, as I conceive, satisfactorily answered every objection you have urged, and, of course, they have only served to establish more firmly in my mind the very favorable sentiments I entertain respecting the practical utility of the proposed railways.

Yours, &c.,

JOHN STEVENS.

Addressed to Gouverneur Morris, Esq., Chairman to the Board of Commissioners for Inland Navigation.

No. 6.

The following is a copy of a letter addressed to Gouverneur Morris, Esq. Chairman to the Commissioners for the Improvement of Inland Navigation:

NEW YORK, March 11, 1812.

Sir:

I lately inclosed, in a letter directed to De Witt Clinton, Esq., a memoir addressed to the Commissioners, which, no doubt, he has communicated to the Board. In this memoir I have endeavored to prove, and I hope not unsatisfactorily, the great superiority of the proposed railways, to canals. The only question then is, whether steam-engines can, without much difficulty, be applied to the purpose of propelling carriages. To

the expression of an opinion on this matter, I certainly have some pretensions to competency. After having then maturely considered the subject, I am firmly convinced that steam-engines can be applied to propelling carriages on these railways, with much more facility than they are now made use of for propelling boats. The machinery of a steam-engine requisite for propelling carriages may be simplified greatly. Cog-wheels, air-pumps, condensing apparatus, plug frame, and fly-wheels can all be dispensed with. Of course, then, the liability of the machinery to derangement will be proportionably diminished. But to place this matter beyond all possibility of doubt, let it be subjected to the infallible test of actual experiment. As has been already stated in my letter to Mr. Clinton, "an experiment sufficiently extensive to ascertain unquestionably the real merits or demerits of this proposed plan could be tried at the expense of two or three thousand dollars." It remains, then, for the Commissioners to determine whether the advantages which this plan promises afford sufficient inducements to authorize them to recommend an appropriation of a moderate sum, to be applied to the making of the necessary experiments. I now pledge myself that the expense of these experiments shall not exceed $3,000.

I am aware how unnecessary it would be to attempt to point out to you the magnitude and importance of the consequences which must necessarily result from these railways and steam-carriages coming into general use. The communications between the extremes of this extensive empire would be rendered beyond all conception rapid, and, at all seasons, and in all weathers, invariably certain. What influence these circumstances would have on the moral, political, and intellectual attainments of the citizens of these States, cannot now be duly appreciated; but unquestionably their permanent prosperity and happiness, as well as temporary ease and comfort, would be greatly promoted.

Should any objections occur, either to yourself or any of the rest of the members of your Board, against the plan I have submitted to their consideration, you will confer a particular favor by stating them to me. Pardon the trouble which my solicitude on this subject occasions. I must confess that, hav-

ing been somewhat instrumental in the introduction of the art of propelling boats by means of steam, I feel ambitious of the honor of introducing the application of the same agent to propelling carriages. And as *steam-boats* have been first brought into practical use on the waters of the Hudson, so I hope and trust that it will not be long before the abundant products of our interior will be conveyed to the banks of this noble river by means of *steam-carriages*.

I am, Sir,

Yours, &c.,

JOHN STEVENS.

No. 7.

The following is a copy of a letter from Mr. G. Morris.

ALBANY, March 16, 1812.

Sir:

I am directed by the Board of Commissioners to transmit the inclosed copy of a report made by the Committee to which your letter was referred. I avail myself of the opportunity to present the assurances of that respect with which I have the honor to be,

Sir, your obedient servant,

GOUVERNEUR MORRIS.

No. 8.

Copy of the report of the Committee.

The Committee to whom was referred the communication from John Stevens, Esq., recommending the construction of a wooden railway, report:

That they have considered the said communication with the attention due to a gentleman whose scientific researches and knowledge of mechanical powers entitle his opinion to great respect, and are sorry not to concur in them.

Mr. Stevens proposes a railway on which a steam-engine is to propel, by a force equal to the competent number of horses, 100 tons at the rate of four miles an hour.

As horses move on the earth, when drawing a weight, it is believed that an equal power must, to produce the same effect,

have sufficient hold on the earth; and it is doubted whether an engine in a wagon can work it forward with as much advantage as horses on a road.

If the engine turn the wheels, and propel the weight by their friction on the railways, it may be questioned whether the effect will equal expectation.

The rims of the wheels (however accurate) will, it is apprehended, impede (by their friction) the progressive motion. Such, at least, would be the case were the wagon drawn by horses.

Friction must be increased, if the logs of the railway should warp. And it may be doubted whether workmen could be found of sufficient skill (even could they have a choice of seasoned timber) to prevent the warping of logs by change of weather from hot to cold, and from wet to dry.

If the rims and railway should not fit exactly, there might result such variance of direction as would bring the rims to cut the rails. But if the wheels fit exactly when the logs are green or wet, they can do so no longer when those logs become seasoned and dry. If, on the contrary, the railway should be constructed of dry or seasoned stuff, wheels, when well fitted to it, would, when rain or damp air had swollen the rails, be squeezed along with difficulty.

Supposing, nevertheless, that non-elastic, incompressible railways were so constructed as not to warp, the slightest failure of foundation on either side would give a bias which (to use a workman's phrase), throwing it out of truth, might occasion its destruction by lateral pressure.

But the result just mentioned would be produced unless foundations are laid below the power of frost, and of materials sufficiently solid to bear the great incumbent pressure proposed in the shock of rapid motion.

And thus we are definitely led to ask whether a railway can be constructed of sufficient strength. It is proposed that one hundred tons be put in motion on it, at the rate of four miles per hour, which is nearly two yards in a second. If this motion were produced by force fixed to the earth, it must not only be equal to the weight multiplied into the velocity, but as much greater as would be needful to overcome the resistance of fric-

tion. No formula has yet been discovered by which to calculate the proportion between power, friction and effect, but experience has demonstrated that friction is always a deduction from power. When that operates (as is supposed to be intended on the present occasion) by friction at the circumference of wheels, overcoming that which is at their axis (and propelling so great a weight), the deduction must be greater than in common cases. Put it, however, for the present, at nothing, and for the weight of wagon, steam-engine and fuel allow nothing; still we shall have force 100 and weight 100 (together 200), working with a velocity of four miles per hour by friction on a railway. It does not seem probable that a way could be made of sufficient strength.

But, if it can, the committee conceive that it must be composed of materials much more solid and durable than wood. Moreover, as it is self-evident that the same way will not serve for carriages going and returning, the expense which would (it is conceived) for a single way exceed that of a canal must be doubled, and would therefore render the construction unadvisable, were it sanctioned by experience.

A true copy from the minutes.

JOHN L. MORTON,
Secretary to the Canal Commissioners.

No. 9.

Answer to the Report of the Committee.

The objections urged against the proposed railways in the above report of the Committee appear to me so void of real foundation that I am constrained to repeat again the sentiment I have already expressed in my answer to the objections brought forward by Mr. Livingston.

These objections "have only served to establish more firmly in my mind the very favorable sentiments I entertain respecting the practical utility of the proposed railways."

The respect, however, due to the gentlemen who constituted this Committee, prompts me to give the following answer:

It is an established principle, resulting from the laws of motion, that all bodies are indifferent to a state of motion or

rest. When, therefore, by any means, a determinative velocity is given to a body, that body would continue to move *ad infinitum*, with the velocity originally impressed upon it, were it not resisted by some other force or power. Thus, were we to suppose a sphere or cylinder, perfectly hard and smooth, to be set in motion upon a horizontal plain, also perfectly smooth and hard, it would revolve around the earth forever, were it not impeded by the resistance of the atmosphere. Gravity, in this case, would have no tendency either to retard or accelerate its motion, as the action of gravity would always be exerted in a direction perpendicular to the line of motion. But a railway cannot, in practice, be constructed of materials perfectly hard and smooth, and, although friction rollers in the hubs of the wheels would take off from the axis a large share of friction, yet still there would remain a considerable quantity to be overcome; what this would amount to in practice cannot theoretically be precisely ascertained. However, the fact of one horse drawing on a railway upwards of fifty tons for several miles, furnishes sufficient data to calculate upon. We may certainly, with great safety, estimate a steam-engine of a two-horse power adequate to the purpose of giving motion to one hundred tons weight, on a horizontal railway. But it is proposed to give to this railway, where necessary, an ascent of one degree. On these occasions, then, there will be required a power equal to somewhat more than one-sixtieth part of the whole weight of one hundred tons; we will call it three thousand five hundred pounds. This, added to the two-horse power necessary to overcome friction, etc., on a horizontal plain, would make a sum total of four thousand pounds. But I have stated already the power of the steam engine at five thousand pounds. But Mr. Latrobe has estimated that "by the aid of a railway, one horse would transport eight tons, supposing the angle of ascent not to exceed one degree." One hundred tons, then, would require twelve and a half horses, allowing two hundred and fifty pounds for each horse; the power of twelve and a half horses would equal only three thousand one hundred and twenty-five pounds, instead of four thousand, as above estimated.

But when it is considered that more than nineteen-twentieths of the whole distance will be nearly on a horizontal level,

which would require no more than a two- or three-horse power, instead of twenty, at which the engine is estimated, we surely need not apprehend a deficiency of power. But "as horses move on the earth when drawing a weight, it is believed that an equal power must, to produce the same effect, have sufficient hold on the earth; and it is doubted whether an engine in a wagon can work it forward with as much advantage as horses on a road."

I must confess I cannot see the force of this objection; and fearful that it might contain something which had escaped my attention, I submitted it to a number of scientific gentlemen, who unanimously concur with me, that, provided the wheels do not slip on the ways, the whole power of the engine is exerted to the best advantage in propelling the carriage forward. There will, no doubt, in proportion as the shackle-pin approaches to, or recedes from, the periphery of the wheel, be a difference in the relative velocity of the carriage and the piston; whereas, the horse and the carriage always move forward with the same velocity.

"If the engine turn the wheels, and propel the weight by their friction on the railway, it may be questioned whether the effect will equal expectation."

No *friction* (except at the hubs) results from the revolutions of the wheels on the railways. *Resistance* will, however, occur, in proportion to the frequency and magnitude of the elevations and depressions of the railways, and their deviations from a horizontal plain.

"The rims of the wheels, however accurate, will, it is apprehended, impede by their friction the progressive motion. Such at least would be the case were the wagon drawn by horses."

It has just now been stated that no friction whatever takes place at the rims of the wheels of a carriage on a railway. This would invariably be the case, whether the carriage were propelled by horses or by a steam-engine.

But the timber of these railways would be liable to warp; I would propose to construct the ways of white pine, twelve inches deep and six wide at bottom, reduced to four at top, and of as great a length as can conveniently be had; say

fifty or sixty feet. Now, if the supports are thirteen feet apart, these pieces will rest on them in five or six different places, where they can be confined immovably. Under such circumstances it is not possible they should warp. As pine, although sufficiently strong to support the weight of the carriages, would be too soft for the rims of the wheels to run on, cap-pieces of oak, two inches thick and four inches wide, must be fastened on the top of the rails.

But these rails will be liable to shrink and swell with "the changes of the weather, from hot to cold, and from wet to dry.' From the observations I have made on this subject, the greatest variations of dimension, in a piece of timber of four inches wide, does not, from the joint operations of these causes, exceed the eighth of an inch; but were it even half an inch, the effects apprehended by the Committee could never occur. The extremities of the rims of the wheels should be about two inches deep, and curving outwards in such a manner as merely to squeeze the rail, when, on any variation of direction, the projections of the rims should be made to come in contact with each side of the rails. As, however, the wheels to which the shackle pins are fixed, are wedged fast to each end of an axis revolving with them, they are necessarily prevented from deviating from the line of draught. And, as the carriages which are drawn behind are firmly attached to each other, they must all pursue one course.

For this reason, I still continue decidedly of the opinion that wooden railways will answer well in practice, and be but little subject to wear. But should experience hereafter prove the fallacy of the ideas I now entertain respecting wooden railways, recourse could at any time be had to iron. Not one shilling of unnecessary expense would be incurred. The iron, whether wrought or cast, could be fastened on the top of the wooden rails, and the business would be done. All the objections which have been urged against wood, as an unfit material, would thus be completely obviated.

But it would be essentially necessary that "foundations be laid below the power of frost, and of materials sufficiently solid." And should it also be found necessary that the wheels should be made to run on iron, the Committee give it as their opinion

that the expense would exceed more than double that of a canal.

In support of this assertion they exhibit no proofs, they advance no calculations. The Commissioners themselves acknowledge that, with respect to a canal, it "would be unpardonably presumptuous should they pretend to accuracy of calculation." The truth is, as I have elsewhere observed, that any estimation of the cost of a canal, such as is contemplated, must, from the nature of the business, be in a great measure conjectural. In their former report they have stated it at five millions, and in their late report, they sum up the whole expense at six millions of dollars. Nine-tenths, or perhaps ninety-nine one-hundredths, of this expense will be incurred for labor bestowed principally in excavating ground at present unexplored. Without taking into calculation, then, the great want of economy and gross abuses which ever attend all public works, there is every reason to believe that were the estimate of the Commissioners doubled, it would fall far short of the ultimate cost of the proposed canal. But as has been already well observed in the report of the Commissioners, the magnitude of the expense is not an object of the first moment. Were a canal to cost ten times as much as the proposed railways, if decidedly preferable, the difference of expense should by no means prevent it being carried into effect. And so, on the contrary, should the railways be found most convenient and eligible, the difference in expense ought not to be regarded.

I shall now proceed to a minute calculation of the cost of railways executed in the most solid and permanent manner. Such, however, is the nature of the work, that the far greater part of it is susceptible of being calculated with a great degree of precision and accuracy.

It will be necessary to reduce the angle of elevation throughout the whole course of the railways so as no part of it shall exceed one degree. To effect this, the hills must be reduced by cuttings, and the valleys raised by mounds. But the expense of these operations will be, in no comparison, as great as would be required for a canal. As the course of a canal must be level, or very nearly so, the depth of the cuttings and the elevation of the mounds must be in proportion. The

Commissioners have estimated the expenditure for "aqueducts, embankments and mounds," at one million of dollars. But as they have estimated the cost of a mound over the Cayuga Lake at nearly one-half of this sum, there would remain then about half a million to be applied to these purposes. But for railways no aqueducts are required, and as a variation of one degree from a horizontal line admits of elevations and depressions of upwards of ninety-two feet in a mile, it perhaps might be practicable to carry the railway through from Albany to Lake Erie, with scarcely any occasion for the removal of the earth. For the reduction, then, of elevations, and the erection of necessary bridges, $250,000 appear more than sufficient; but to silence all cavil, we will put it at half a million.

I have met with no person yet, the least conversant with the subject, who entertains the smallest doubt about the strength of wooden supports. Wood, it must be conceded, falls far short of stone or brick in respect of durability. But, as I have already stated, it may still be the most economical material. Although, then, I can see no valid objection against the use of wood, I will, merely to satisfy the gentlemen of the Committee, substitute stone orbrickin the following estimate.

It may be urged that extensive tracts in the course of the railways are destitute of stone proper for the purpose, and that clay for the making of bricks cannot be found everywhere. It will not, I presume, be contested, that in a distance of three hundred miles through a country no section of which, except from Albany to Schenectady, is sandy, a number of places will be found affording good building stone, and good clay for making bricks. By commencing the railway in the vicinity of such places, stone and brick could be transported to wherever these articles may be wanted, at a trifling expense. I have stated the actual expense of transportation at fifty cents per ton for three hundred miles. Supposing, then, that some parts of the way may require a transportation of materials a distance of twenty miles, this, at the above rate, would amount to three and a third cents per ton. But, to avoid all dispute, let the average amount of expense of transportation of materials be estimated at twelve and a half cents per ton. We will, in the first instance, suppose the pillars are composed of brick,

six feet high, and eighteen inches square. Each pillar will contain about two hundred bricks. In every thirteen feet of the railway three pillars will be required, or six hundred bricks.

600 bricks, at $3 per 1,000, is	$1.80
6-10ths of a day's work of a mason	75
" " " " laborer	60
Lime	50
Digging, &c.	35
	$4.00

for every thirteen feet of railway, or $20 a chain = $1,600 per mile. Should stone be used, we may add fifty per cent., or $2,400 per mile. Estimating timber at twelve and a half cents a foot, which is certainly more than double what it may be got for, the timber for the ways and the carpenters' work would come to about $1,500 per mile. There cannot be a doubt that wrought iron is, on various accounts, preferable to cast iron for the wheels to run on, provided it is of sufficient thickness. I would propose, then, to take, for this purpose, bar iron of half an inch thick and four inches broad. This may be had, at retail price, at six cents per pound; but certainly at much less by the larger quantity. It takes about four cubic inches of wrought iron to make a pound; each inch, then, of these bars will weigh half a pound, and four of them will weigh two pounds per inch, or twenty-four pounds per foot, at six cents per pound = $1.44 cents per foot, or $7,603 per mile.

Bar iron plates	$7,630	
Brick pillars	1,600	
Timber ways	1,500	
	$10,703	
Or		$3,210,900
for the whole distance of three hundred miles.		
For reducing elevation, &c.		500,000
Total		$3,710,000

Should stone, however, be used, the expense would be enhanced $800 per mile, or $240,000 for the whole distance; making a sum total of $3,950,000.

Thus, then, executed in the most durable manner with stone

or brick pillars and iron ways, this great undertaking could be completed for a sum certainly not exceeding four millions of dollars.

The only article of expenditure in the foregoing estimate liable to uncertainty is the reduction of elevations of the ground throughout the course of the railways, so as not to exceed one degree. But the Commissioners must have erred very widely from the truth in that part of their estimate relative to the reducing hills, and raising valleys to a horizontal plain, or nearly so, or the sum assigned to the foregoing object must be more than sufficient. The shortest distance between Albany and Lake Erie is two hundred and eighty miles, whereas the Commissioners, in their late report, have conceived it necessary, in order to preserve the requisite levels, to extend the route of the canal, in a circuitous course, to three hundred and fifty miles. With a rise and fall of ninety-two feet in a mile, it will by no means be necessary for the railways to make so extensive a circuit. It probably will be practicable to conduct these ways by a route not exceeding three hundred miles. This will not only be a saving in the expense of construction, but—what will be much more important—it will effect a great saving in the time and expense of transportation.

I have now answered, and I expect satisfactorily, every objection made by the Committee. These objections are aimed principally against the use of wood. As iron, stone, or brick are now substituted, they, of course, become inapplicable. And as the doubt of the Commissioners expressed—"whether an engine in a wagon can work it forward with as much advantage as horses on a road"—has not the least foundation, the only objection then remaining is, that the expense of railways would be more than double that of a canal. But if the above estimate is not very erroneous, the railways will not cost one-half as much as a canal. But as the Commissioners in their late report have abandoned the idea of taking the waters of Lake Erie in an inclined plane to the Hudson, a never-failing supply of water will be required at the summit level or levels. It is a notorious fact that tracts of country become more or less arid as they become cleared of timber. Whether, then, a sufficient supply of water will at all times be commanded

when the country through which the canal has to pass becomes fully populated, is a very serious and important question. Besides, canals are liable to innumerable casualties. Sudden torrents frequently produce incalculable mischief. It is often extremely difficult to prevent and stop effectually leaks in a loose, porous soil. The frosts in winter and droughts in summer will occasion cracks in the clay. Vermin of various descriptions are perpetually perforating holes. The roots of trees are constantly penetrating into the loose earth, and occasioning leaks. The locks are perpetually requiring repairs. Whereas, I know of no casualties to which railways, constructed as now proposed, are liable. Whilst the materials last they must ever remain unaffected by anything short of an earthquake. When it is considered, too, that the travel on these ways remain always, winter and summer uninterrupted—that there are no locks or other circumstances to occasion delay, that the expense of transportation would not be more than one-third of that on a canal, and the original expense of construction not more than one-half—when, I say, all these things are taken into consideration how can we hesitate to give a preference to the railways?

But, notwithstanding the many inconveniences I have enumerated, the great utility of canals is "sanctioned by experience;" whereas the practical utility of railways on the proposed construction, remains yet to be ascertained by actual experiment.

But when millions are to be expended, shall a few thousand dollars be grudged to make the experiment on an object promising so fairly?

But it would be useless to pursue the subject further. Should what has been already said be insufficient to open the eyes of the Committee, I have only to lament that their blindness on this occasion will certainly be followed by a future regret. A discovery, more especially a physical one, when once made, and its development fairly exhibited before the public, can never, if of any importance, be lost or suppressed. Sooner or later, then, the improvement now proposed will be brought into general use, and, if I mistake not, long before the projected canal will be completed.

It will obviously occur that a number of passages contained in the report of the Committee are not particularly noticed. If, for instance, no particular notice is taken of the following passages, viz.: "If this motion were produced by force fixed to the earth, it must not only be equal to the weight multiplied into the velocity,"—again—"No formula has yet been discovered by which to calculate the proportion between power, friction, and effect."—"Still we shall have force 100, and weight 100 (together 200), working with a velocity of four miles per hour by friction on a railway,"—if these and some other passages are not particularly noticed, yet a due attention to what has been advanced in the above reply to the Committee's objections, will satisfy every impartial reader that they have been *all* substantially answered.

NEW JERSEY THE PIONEER IN AMERICAN INDUSTRIAL PROGRESS.

In accepting the invitation to participate in the celebration of the semi-centennial anniversary of the founding of the New Jersey Historical Society at Newark, Mr J. Elfreth Watkins, of the Smithsonian Institution, now Curator of Technological Collections in the National Museum at Washington, called attention to the following interesting facts, showing New Jersey's influence upon the introduction and invention of the steam engine, steamship, locomotive and electric telegraph in America.

First.- The first steam engine on the Western Continent was erected at the Belleville Copper Mines, near Newark, in 1753, by Hornblower, sixteen years before Watt began his investigations.

Second.-- The first steamboats driven by a single and twin screw propellers were constructed by John Stevens, at Hoboken, in 1802 and 1804.

Third The *Phœnix*, the first steamboat to navigate the ocean, was designed, constructed and navigated by Jerseymen – John Stevens and his son, Robert L. Stevens, in 1807-1808.

Fourth The first charter for a railroad in America was granted by the Legislature of New Jersey in 1814, for a railway from Trenton to New Brunswick during the war of 1812.

Fifth The machinery of the *Savannah*, the first steamship to cross the Atlantic ocean, was constructed at the Vail Works, Speedwell, near Morristown, N. J., in 1818.

Sixth- The first steam locomotive in America to convey human beings on a railroad track was constructed at Hoboken in 1825.

Seventh- The first successful experiments with the electromagnetic telegraph, based upon the discoveries of Prof. Henry, of Princeton College, were made by Vail and Morse at Speedwell Works, near Morristown, in 1838.

The invention and introduction in America of the steam engine, steamship, the locomotive and the telegraph- the mightiest factors in modern civilization - were thus due, in a great degree, to Jerseymen.

ENERGY EQUIVALENTS.*

BY EDWARD J. WILLIS, M. E., '88.

There frequently occur, in the course of engineering work, calculations of efficiency and consumption which are, more or less, long and tedious. The figures given in following paragraphs will reduce any such calculation to a case of simple multiplication or division. This not only saves time, but greatly decreases the chance of errors, which can often pass unnoticed in many of the rarely understood and complicated expressions which such calculations involve. Only full theoretical values or equivalents are given, and when the delivery is not up to the figure the deficiency is the loss in the transformation, or if the consumption is greater than the equivalent, such excess is the waste of the process. Some of the equivalents are, at the present time, uncertain, and the figures given are subject to such changes as their definite determination will involve. Joule's equivalent has been used as 776, which is considered a conservative figure, as is also the light equivalent of 1 C. P. = 620 foot-pounds per hour. Logarithms of each number have been inserted, and the reciprocal of any equivalent will be found under its proper heading.

WORK.

ONE (1) HORSE-POWER =

In Foot-Pounds.	33,000 (log. 4.518514) foot-pounds per minute.
	550 (log. 2.740363) foot-pounds per second.
	1,980,000 (log. 6.296665) foot-pounds per hour.
In B. T. U.	.709 (log. $\bar{1}$.850646) B. T. U. per second.
	42.53 (log. 1.628652) B. T. U. per minute.
	2,552 (log. 3.406710) B. T. U. per hour.

* This matter appeared in *American Machinist* of April 25, 1895 and is here presented in a tabulated form which it is hoped will render it even more readily available.—Ed.

In Pounds Steam.	2,219 (log. .346105) pounds of steam per hour at 80 pounds pressure (95 pounds absolute).
	2,2104 (log. .344441) pounds steam at 100 pounds pressure (115 pounds absolute).
In Combustion.	.002933 (log. $\bar{3}$.467312) pounds carbon consumed per minute, or .176 ($\bar{1}$.24551) pounds carbon per hour.
	.1823 (log. $\bar{1}$.260787) pounds ordinary coal per hour.
	.1169 (log. $\bar{1}$.067815) pounds = .0157 gals.
	(log. $\bar{}$ 2.19590) ordinary petroleum per hour.
	.1276 (log. $\bar{1}$. 105781) pounds good kerosene per hour.
	3.925 (log. .593890) cubic feet ordinary house gas per hour.
In Electricity, and Light.	746 (log. 2. 872739) Watts, or
	2.750 (log. 3.43933) candle power.

ONE (1) FOOT-POUND PER SECOND =

In H. P.	.001818 (log. $\bar{3}$.259594) horse power.
In Electric Light.	1.3565 (log. .132343) Watts, or
	5 (log. .698970) candles.
In B. T. U.	4.64 (log. .666515) B. T. U. per hour.
In Steam.	.004034 (log. $\bar{3}$.605699) pounds steam at 80 pounds pressure (95 pounds absolute) per hour.
	.004018 (log. $\bar{3}$.604035) pounds steam at 100 pounds pressure (115 pounds absolute) per hour.

ONE FOOT-POUND PER MINUTE =

In H. P.	.0000303 (log. $\bar{5}$.481443) H. P.
In Electric Light.	.0226 (log. 2.354108) Watts.
	.0833 (log. $\bar{2}$.920820) candles.
In B. T. U.	.07733 (log. $\bar{1}$.888348) B. T. U. per hour.

IN STEAM. .00006723 (log. 5.827548) pounds steam at 80 pounds pressure (95 pounds absolute) per hour.

.00006696 (log. 5.825874) pounds steam at 100 pounds pressure (115 pounds absolute) per hour.

IN ROTARY DELIVERY.

ROTARY DELIVERY TO GET H. P.

A force of 52.41 (log. 1.719333) pounds at an arm 1 foot long, making 100 revolutions per minute, gives one H. P.

A force of 100 pounds, acting on an arm 1 foot long, making 52.41 (log. 1.719333) revolutions per minute, gives 1 H. P.

A force of 100 pounds, acting on an arm .5241 (log. 1.619333) foot = 6¼ inches long, making 100 revolutions per minute, gives 1 H. P.

A force of 100 pounds, acting on an arm 1 foot long, and making 100 revolutions per minute, gives 1.904 (log. .279665) H. P.

Roughly we have 1 H. P. for 100 pounds pull on a belt running over a 1-foot pulley (1 foot diameter), making 100 revolutions per minute.

HEAT.

ONE B.T.U. (1 POUND WATER RAISED 1 FAHR.) =

776 (log. 2.889862) foot pounds.

ONE B.T.U. CONSUMED PER SECOND

B.T.U. TO WORK, LIGHT AND ELECTRICITY.

1.411 (log. .149500) horse power, or
1,052.6 (log. 3.022263) Watts, or
3,880 (log. 3.588832) candle power.

ONE B.T.U. PER MINUTE

.023515 (log 2.371345) H.P. or
17.5433 (log. 1.244112) Watts, or
64.66 (log. 1.810569) candles.

ONE B.T.U. PER HOUR.

.000392 (log .4.593200) H. P. or
.2924 (log. 1.465977) Watts, or
1.078 (log. .032619) candles.

ONE POUND OF STEAM.

STEAM TO WORK, LIGHT AND ELECTRICITY.

At 100 pounds pressure (115 absolute) takes .7962 (log. 2.901000) pounds carbon, or .0824 (log. 2.915927) pounds ordinary good coal to make it from water at 62° Fahr., assuming no loss; it contains
1,154.5 (log. 3.062368) B. T. U., or
895,892 (log. 5 .959315) foot-pounds.
If it were consumed in one hour it would represent—with no loss—
14,931 (log. 4.174089) foot-pounds per minute, or
.45247 (log. 1.655565) H. P., or
337.6 (log. 2.528304) Watts, or
1,244.5 (log. 3.094893) candles.

ONE POUND OF STEAM.

STEAM TO WORK, LIGHT AND ELECTRICITY.

At 80 pounds pressure (95 absolute) takes .0793 (log. 2.899328) pounds carbon, or .0821 (log. 2.914343) pounds ordinary good coal to make it from water at 62° Fahr., assuming no loss. It contains
1,150 (log. 3.060698) B. T. U., or
892,400 (log. 5.950551) foot-pounds.
If it be consumed in 1 hour with no loss=
14,873 (log. 4.172400) foot-pounds per minute or
.4507 (log. 1.65388) H. P. or
336.2 (log. 2.526625) Watts, or
1239 (log. 3.09322) candles.

ONE POUND OF CARBON CONSUMED IN 1 HOUR

COMBUSTION.	14,500 (log. 4.161368) B. T. U. per hour,
	11,252,000 (log. 7.051230) foot-pounds per hour.
	5.683 (log. .754565) H. P.,
	4,240 (log. 3.627304) Watts,
	15,630 (log. 4.193895) candles.
FUELS TO B. T. U.	15 (log. 1.176091) pounds water evaporated from and at 121° Fahr.
	12.56 (log. 1.099000) pounds steam made from water at 62° Fahr., to steam at 100 pounds pressure (115 pounds absolute).
STEAM WORK.	12.61 (log. 1.10067) pounds steam made from water at 62° Fahr. to steam at 80 pounds pressure (95 pounds absolute).

ONE POUND ORDINARY KEROSENE CONSUMED PER HOUR

LIGHT AND ELECTRICITY.	20,000 (log. 4.301030) B. T. U. per hour,
	15,520,000 (log. 7.190892) foot-pounds per hour,
	7.838 (log. .894227) H. P.,
	5,847 (log. 3.766966) Watts,
	21,560 (log. 4.333557) candles,
	20.7 (log. 1.316053) pounds water evaporated from and at 212° Fahr.,
	17.325 (log. 1.238673) pounds water from 62° Fahr. to steam at 100 pounds pressure (115 pounds absolute),
	17.40 (log. 1.240050) pounds water at 62° Fahr. to steam at 80 pounds pressure (95 pounds absolute).

ONE CUBIC FOOT ORDINARY ILLUMINATING GAS PER HOUR

650 (log. 2.812913) B. T. U. per hour.
504,400 (log. $\bar{5}$.702775) foot-pounds per hour.
.25475 (log. $\bar{1}$.406110) H. P.
190 (log. 2.278849) Watts.

700 (log. 2.845440) candle power.
.6729 (log. 1.827936) pounds water evaporated from and at 212° Fahr.
.563 (log. $\bar{1}$.750585) pounds water at 62° Fahr. to steam at 100 pounds pressure (115 pounds absolute).

LIGHT.

ONE CANDLE POWER

LIGHT TO WORK.	.00036364	(log. $\bar{4}$.560672) H. P.
	.2713	(log. $\bar{1}$.433411) Watts.
	12	(log. 1.079181) foot-pounds per minute.
	720	(log. $\bar{2}$.857332) foot-pounds per hour.
B. T. U.	.015464	(log. $\bar{2}$.189319) B. T. U. per minute.
ELECTRICITY, STEAM AND COMBUSTIBLES.	.92783	(log. $\bar{1}$.967470) B. T. U. per hour.
	.0008037	(log. $\bar{4}$.905102) pounds steam per hour at 100 pounds pressure (115 pounds absolute).
	.0008068	(log. $\bar{4}$.906772) pounds steam at 80 pounds pressure (95 pounds absolute).
	.000064	(log. $\bar{5}$.806102) pounds.
	.448	(log. $\bar{1}$.6512) grains carbon per hour.
	.0000661	(log. $\bar{5}$.820201) pounds ordinary coal per hour.
	.0000464	(log. $\bar{5}$.66644) pounds.
	.32475	(log. $\bar{1}$.511538) grains.
	.001531	(log. $\bar{3}$.184975) cubic inches.
	.000006628	(log. $\bar{6}$.821342) gallons ordinary kerosene per hour.
	.001427	(log. $\bar{3}$.154557) cubic feet ordinary gas per hour.

ELECTRICITY.

ONE (1) WATT

ELECTRICITY TO WORK.	.0013405	(log. $\bar{3}$.127241) H. P.
	.057	(log. 2.755913) B. T. U. per minute.
B. T. U.	3.42	(log. .534064) B. T. U. per hour.

STEAM, LIGHT AND COMBUSTIBLES.	44.24 (log. 1.645775) foot-pounds per minute.
	2,654.4 (log. 3.423966) foot-pounds per hour.
	3.6863 (log. .566591) candle power.
	.000236 (log. $\bar{4}$.372696) pounds.
	1.65 (log. .217794) grains carbon per hour.
	.000171 (log. 4.233034) pounds.
	1.197 (log. .078132) grains good kerosene per hour.
	.005262 (log. $\bar{3}$.721151) cubic feet ordinary illuminating gas per hour.

Obituary.

ANDREW SHIEBLER, '92.

Andrew Shiebler died on August 11, 1895, just one month before his 24th birthday, having been born in Brooklyn, Sept. 9 1871.

His earlier school days were passed in the public schools of Brooklyn till 1883, when he entered the Polytechnic Institute. In 1886 he entered the Stevens High School, and after spending two years in preparation was admitted to the Institute with the class of '92.

His whole course was marked by faithful, honest work, so that he was graduated in 1892 with a fine record.

He entered, almost immediately, the employment of B. F. Sturtevant Co., of Boston, Mass., as a draughtsman. His ability in this line was marked, and he was rapidly given charge of the laying out of very important work, in which he proved the wisdom of his superiors in their choice.

In March, 1894, he was placed in charge of the draughting-room of the Philadelphia branch, and again proved his ability by the successful manner in which he handled the business at this point.

In disposition he was quiet and retiring, seeming to care more for the studious than the social side of life, yet when a friendship was once established, there could be no firmer, truer friend than he.

It is truly said of him, in the words of his employers, "He was always in earnest, always ready for anything that came to hand, and very self-reliant. He was quick to catch an idea and embody it in tangible form, and in all things was a man with whom it was a pleasure to work. The remark has frequently been made that he was the best man that ever went out of our draughting-room."

His close application told on him when he was taken with typhoid fever, and he died after a very short illness on August 11, 1895, universally admired and loved by his associates.

The funeral services were held at the home of his parents, 278 Berkeley Place, Brooklyn, on Tuesday, August 13.

ATHLETICS.

FOOT-BALL.

IN view of the fact that of the fifteen men who played on the 'Varsity team last year eight graduated with the class of '95 and four left college, and that the available material at the opening of the season of '95 did not appear promising, it was deemed best, rather than place an inferior team in the field, not to have any 'Varsity team this year. In order that the interest in the game be maintained, and to develop the material that will likely be suitable for next year's team, it was decided to have a series of inter-class games, each class to play one game with each of the other three classes. The schedule of these inter-class games is as follows:

SCHEDULE OF INTER-CLASS FOOT-BALL GAMES.

'97	*vs.* '99	Friday, October	18
'96	" 98	Tuesday, "	22
'96	" '99	Friday, "	25
'97	" '98	Tuesday, "	29
'96	" '97	Friday, Novemb'r	1
'98	" '99	Tuesday, "	5

These games resulted as follows:

JUNIORS *vs.* FRESHMEN—SCORE, 24 TO 4.

Contesting teams:

'99		'97.
Hagstoz (Capt.)	Right end	Macbeth.
Campbell, G.. / Halsey	Right tackle	Chapin.
Halsey / McCracken ..	Right guard	Mott.
Beck	Center	Towne.
Kirby	Left guard	Davie.
Taylor	Left tackle	Hunter. / Munby.
Stanley	Left end	Pryor.
Myers	Quarter-back	Grady.
Christie	Left half-back	Christy.
Stover	Right half-back	Hutchins.
Westerfield	Full-back	Mathey.

Referee, H. F. Cuntz, '93. Umpire, E. Kemble, '95. Linesmen—W. Kyle, W. H. Jennings, Jr., '96.

SCORE BY INNINGS:

	First Half.	Second Half.	
'97	14	10	24
'99	0	4	4

SENIORS *vs.* SOPHOMORES—SCORE, 22 TO 8.

Contesting teams:

'96.		'98.
Morris.. } Pope... }	Left end	Buckley.
Schimmel	Left tackle	Kellogg.
Borland	Left guard	Littlejohn.
Woodward	Center	Lunger.
Evertsz	Right guard	Brett.
Christy	Right tackle	Bang.
Jennings... } Kollstede .. }	Right end	Welch.
Willet	Quarter-back	Scott.
Gunnison	Left half-back	Kennedy.
Hunt (Capt.)	Right half-back	Sofio.
Bruckner	Full-back	Hughes (Capt.)

Referee, E. Kemble, '95. Umpire—First half, W. H. Jennings, Jr., '96; second half, E. L. Decker, '96. Linesmen—T. F. Hussa, '96; W. Kyle.

SCORE BY INNINGS.

	First Half.	Second Half.
'96	4	18.....22
'98	4	4..... 8

SENIORS *vs.* FRESHMEN—SCORE, 34 TO 0.

Contesting teams:

'96.		'99.
Morris	Left end	Stanley.
Schimmel	Left tackle	Taylor.
Woolson	Left guard	Kirby.
Woodward	Center	Beck.
Evertsz	Right guard	Le Porin. MacCracken.
Christy	Right tackle	Campbell.
Hunt (Capt.)	Right end	Habben. Hagstoz (Capt.).
Willet	Quarter-back	King.
Gunnison	Left half-back	Christie.
Hardie, L. H	Right half-back	Stover.
Borland	Full-back	Westerfield.

Referee, W. Terry. Umpire, R. Scott, '98. Linesmen—R. Boettger, '98; E. Campbell, '96.

SCORE BY INNINGS.

	First Half.	Second Half.
'96	8	26.....34
'99	0	0..... 0

JUNIORS *vs.* SOPHOMORES—SCORE, 16 TO 6.

Contesting teams:

'98		'97.
Welch	Right end	Macbeth.
Bang	Right tackle	Chapin. / Mott.
Brett	Right guard	Cromwell.
Lunger	Center	Towne.
Littlejohn	Left guard	Davey.
Kellogg	Left tackle	Munby.
Buckley .. / Boettger ..	Left end	Brune. / Pryor. / Grady.
Scott	Quarter-back	Pryor. / Grady.
Sofio	Right half-back	Hutchins.
Lane	Left half-back	Christy.
Hughes	Full-back	Mathey.

Referee, E. Kemble, '95. Umpire, W. Kyle.

SCORE BY INNINGS.

	First Half.	Second Half.	
'98	0	6	6
'97	10	6	16

SENIORS *vs.* JUNIORS—SCORE, 44 TO 0.

Contesting teams;

'96		'97.
Jennings	Left end	Grady.
Schimmel	Left tackle	Munby.
Woolson	Left guard	Davey. / Koch.
Woodward	Center	Towne.
Evertsz	Right guard	Cromwell.
Christy	Right tackle	Mott. / Davey.
Pope	Right end	Macbeth.
Willet (Act'g Capt.)	Quarter-back	Pryor (Capt.).
Gunnison	Left half-back	Christy.
Hardie, L. H	Right half-back	Hutchins.
Borland	Full-back	Mathey. / Williamson, J, '98;

Referee, H. Cuntz, '93. Umpire, E. Kemble, '95. Linesmen—R. Scott. A. T. Hagstoz, '98.

SCORE BY INNINGS.

	First Half.	Second Half.	
'96	24	20	44
'97	0	0	0

SOPHOMORE *vs.* FRESHMAN—SCORE 22 TO 0.

Contesting teams:

'98.		'99.
Buckley	Left end	Stanley.
Boettger	Left tackle	Taylor.
Littlejohn	Left Guard	Kirby. / Campbell.
Lunger	Center	Beck.
Brett	Right guard	MacCracken.
Bang	Right tackle	Halsey.
Welch	Right end	Hagstoz.
Scott	Quarter back	Myers. / King.
Kennedy	Left Half-back	Christie.
Sofio	Right Half-back	Stover.
Hughes	Full-back	Westerfield.

Referee, H. Cuntz, '93. Umpire, A. W. Gunnison, '96. Linesmen—A. E. Whitman, '96; H. C. Messimer, '96.

SCORE BY INNINGS.

	First Half.	Second Half.	
'98	10	12	22
'99	0	0	0

LACROSSE.

THE fall practice began immediately after the opening of the Institute and was continued until the first of the series of inter-class foot-ball games was played.

At the close of these games, or about November 1, regular practice is to be resumed, and during the winter the team will work in the gymnasium. Possibly, too, some plan will be devised to give the team an opportunity to get some stick practice during the winter term.

INSTITUTE NOTES.

JOHN M. HANSEN, Class '91, recently deceased, requested that his books and tools used at the Institute should be presented to such student as might be selected by the faculty, and also that a direct-vision spectroscope which he owned should be given to the physical cabinet of the Institute. Both of these requests have been carried out, and the reception and disposal of the articles is hereby acknowledged and recorded.

H. MORTON, President.

THE REGULAR MEETING of the Executive Committee of the Alumni Association was held at the office of the president of the Association, Mr. H. de B. Parsons, No. 22 William street, New York City, on Saturday, Oct. 5, 1895.

Besides attending to routine business, a committee, consisting of Messrs. W. H. Bristol, Kenneth Torrance and A. Riesenberger, was appointed to consider ways and means to further the growth of the Alumni Building Fund and the general improvement of the Institute, and to report at the next meeting of the Executive Committee, to be held in January.

The committee, named above, would be pleased to receive any suggestions that Alumni care to make in regard to any improvements, as outlined in the resolution.

The deaths of Messrs. J. M. Hansen, Jr., '91, Andrew Shiebler, '92, and J. H. Murray, '92, were reported; and it was ordered that notices of the deaths of these members of the Alumni Association be printed in the INDICATOR.

DR. STILLMAN devoted a considerable portion of his summer vacation to the preparation of the manuscript for a text-book on "Engineering Chemistry," which will probably be ready for the press before the end of the year.

DURING THE ABSENCE of Prof. Geo. L. Manning, the Assistant Professor of Physics and Chemistry, Mr. M. E. Craft, '95, will conduct the recitations in chemistry of the Freshman Class.

President Morton will deliver one lecture a week in physics to this class, and the recitations in this subject will be taken by Mr. Ganz.

THE VARIOUS CLASSES have organized with the following officers:

SENIOR CLASS.

President, Samuel Hollingsworth.	*Treasurer*, A. W. Gunnison.
Vice-President, H. R. Summerhayes.	*Historian*, William C. Maul.
Secretary, S. A. Hasbrouck.	*Foot-Ball Captain*, C. H. Hunt.

JUNIOR CLASS.

President, William D. Ennis.
Vice-President, Warren Davey.
Secretary, William I. Thomson.
Treasurer, Joseph M. Towne.
Foot-Ball Captain, F. L. Pryor.

SOPHOMORE CLASS.

President, H. R. Davis.
Vice-President, Charles Warner.
Secretary, G. R. Hemminger.
Treasurer, F. I. Baker.
Foot-Ball Captain, R. S. Hughes.

FRESHMAN CLASS.

President, F. J. Le Porin.
Vice-President, C. H. Christie.
Secretary, H. G. Taylor.
Treasurer, W. P. Humphreys.
Foot-Ball Captain, A. T. Hagstoz.

The election of officers in the Engineering Society, the Musical and Yacht Clubs, for the current year, resulted as follows:

ENGINEERING SOCIETY.

President, Wm. J. A. Boucher.
Secretary, W. H. Dickerson.
Treasurer, W. J. Rusling, Jr.

GLEE CLUB.

President, E. J. Munby.
Vice-President, O. A. Pope.
Sec'y and Treas., P. D. Wagoner.
Leader, W. H. MacGregor.

MANDOLIN CLUB.

President, A. W. Gunnison.
Sec'y and Treas., H. C. Mathey.
Leader, G. Kollstede.

BANJO CLUB.

President, H. C. Messimer.
Sec'y and Treas., H. M. Hardie.
Leader, R. G. Messimer.

S. S. S.

President, J. B. Kreischer.
Vice-President, A. H. Whitman.
Secretary, R. S. Scott, Jr.
Treasurer, R. C. Post.

STEVENS YACHT CLUB.

Commodore, B. C. Clark.
Vice-Commodore, C. H. Hunt.
Rear-Com., G. Kollstede.
Fleet Capt., G. F. Gilmore.
Secretary, S. A. Hasbrouck.
Treasurer, F. Overton.
Measurer, H. Summerhayes.

THE MEMBERSHIP of the several classes of the Institute is as follows: Seniors, 63; Juniors, 67; Sophomores, 63; Freshmen, 69.

The applicants for the class '99 numbered about 100; the successful candidates with their addresses are:

H. P. Ahrnke, 906 Bloomfield street, Hoboken, N. J.
R. C. Aldrich, 123 Park Place, Passaic, N. J.
F. W.Beale, 315 West 104th street, New York, N. Y.

G. H. Beck, 314 Hancock street, Brooklyn, N. Y.
H. Berg, 200 Glenwood avenue, New York, N. Y.
L. Berg, 52 West Eighty-third street, New York, N. Y.
G. Brown, 825 President street, Brooklyn, N. Y.
H. A. Brown, Jr., 825 President street, Brooklyn, N. Y.
G. H. Burke, 209 West Eighth street, Plainfield, N. J.
E. Buxo, care of J. Vidal, Pier 10, East River, New York, N. Y.
G. Campbell, Cold Spring on Hudson, N. Y.
E. A. Carpenter, 171 West Seventh street, Roseville, N. J.
J. A. Cartwright, 57 Elm street, New York, N. Y.
W. D. Church, 17 Craig Place, Plainfield, N. J.
C. D. Christie, Nyack, N. Y.
G. C. Cole, 19 South Maple avenue, East Orange, N. J.
H. W. Crowell, 634 High street, Newark, N. J.
R. J. Decker, 206 Lincoln Place, Brooklyn, N. Y.
R. M. Dodge, 1032 Gates avenue, Brooklyn, N. Y.
J. F. Edmunds, Davids Island, New York Harbor.
Geo. F. Everitt, Hackettstown, N. J.
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F. A. Guenther, 331 Hudson street, Hoboken, N. J.
J. Habben, 695 Broadway, Paterson, N. J.
A. T. Hagstoz, 53 William street, East Orange, N. J.
Wm. C. Halsey, 286 Bergen avenue, Jersey City, N. J.
J. S. Henry, 26 Washington street, East Orange, N. J.
C. S. Hoffman, 356 Henry street, Brooklyn, N. Y.
H. Humphreys, San Remo Hotel, Seventy-fifth street and Central Park, New York, N. Y.
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R. P. Jennings, 339 York street, Jersey City, N. J.
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A. Wilson, 38 Ridge street, Orange, N. J.
S. C. Yeaton, 210 Ninth street, South Brooklyn, N. Y.

INSTITUTE PERSONALS.

'75.

THE "Iron Trade Review," Cleveland, O., Aug. 8, 1895, contains the following:

Adolph Sorge, Jr., M. E., who has been for the past year and a half with Fraser & Chalmers, of Chicago, as superintendent and in charge of the city sales department, has decided to branch out for himself, and has opened an office in room 1533 Marquette Building, Chicago, as a consulting engineer, making a specialty of foundry practice. Mr. Sorge is especially well equipped for this work, being a graduate of Stevens Institute, '75, and having for the past twenty years devoted himself to machine-shop and foundry work. His standing as an expert foundryman is of the highest, and combining a practical knowledge with the most advanced theoretical ideas, Mr. Sorge will undoubtedly find success in his venture. Mr. Sorge will have arrangements whereby he can furnish laboratory work, both physical and chemical, and will be in position to help foundrymen out of any difficulties they may encounter in their practice.

'76.

GUS C. HENNING, who represented the American Society of Mechanical Engineers at the Conference on Unification of Methods of Testing Materials of Construction, held Sept. 9–11, 1895, at Zurich, Germany, gives, in the *American Machinist*, Oct. 17, 1895, brief abstracts of six interesting papers presented to the conference.

WILLIAM KENT is Associate Editor of *Engineering News*, and has special charge of all matters relating to mechanical and metallurgical engineering.

A. W. STAHL, Naval Constructor, U. S. N., read a paper entitled "Experimental Test of the Armored Side of the U. S. S. *Iowa*," at the annual meeting of the Society of Naval Architects and Marine Engineers, in New York City, November 7.

'77.

E. P. ROBERTS, President of the Correspondence School, Cleveland, Ohio, contributed an article to *Cassier's Magazine* for June, 1895, in which he gives the general method of conducting the instruction in Correspondence Schools, and cites the various advantages of such a course.

'80.

DURAND WOODMAN was elected Secretary and Treasurer of the New York Section of the American Chemical Society, at the meeting held Oct. 4, 1895.

'83.

A. P. HENDERSON, who was formerly in the Construction and Repair Department of the Norfolk Navy Yard, is now in the Marine Department of the Babcock & Wilcox Co., 30 Cortlandt st., New York City.

ADDISON ALEX. RIGHTER is Secretary of the Corruganza M'f'g Co., whose works have been removed to Garratt Mills, Summers Town, S. W., London, England.

'84.

CHARLES F. PARKER was married on Nov. 20 to Miss Amy V. Sackett.

CHARLES W. WHITING is Superintendent of the foundry and machine shop of Van Bergen & Co., Ltd., at Carbondale, Pa.

Cassier's Magazine, June, 1895, contains an article by Mr. Whiting on "An American Gravity Railroad." The railroad described and illustrated is the Carbondale and Honesdale line, known as the Gravity System of the Delaware and Hudson Canal Company.

'86.

E. P. MOWTON is connected with the law department of the Fidelity & Casualty Co., 97 Cedar st., New York City.

'90.

CHARLES J. EVERETT, Jr., is consulting and constructing engineer, Havemeyer building, 26 Cortlandt st., New York City.

E. H. WHITLOCK is Secretary and Treasurer of The Miles Refrigerating & Ice Machine Co., 415 Main St., Cincinnati, O.

'91.

C. G. ATWATER is draftsman for the Solvay Process Co., Coke Oven Dept., Syracuse, N. Y.

GEO. C. HOLBERTON is in the employ of the General Electric Co., 15 First St., San Francisco, Cal.

JULIUS OELBERMANN has accepted a position as salesman for the Link Belt Engineering Co., Nicetown, Pa.

FRANCIS N. SANBORN is connected with the Susquehanna Coal Co., at Wilkes-Barre, Pa., as mechanical engineer. He was married on October 31 to Miss Bertha Eunice Rockwell, daughter of Mr. C. Lerdy Rockwell, of Glens' Falls, N. Y.

'92.

HAROLD B. ATKINS has left the employ of the Pintsch Compressing Co.'s Boston works, and may now be addressed at Roselle, N. J.

WILLIAM O. LUDLOW, of the firm of Ludlow & Valentine, architects, 97 Franklin Street, New York City, is engaged upon the design and construction of a number of buildings in the vicinity of New York City.

'93.

O. G. DALE is inspector for the Mutual Fire Insurance Co., 45 Cedar Street, New York City.

EDWIN R. DOUGLAS is pursuing a post-graduate course in physics at Harvard University, Cambridge, Mass. His present address is 54 Hammond Street, Cambridge, Mass.

'94.

JOSEPH COTTIER'S address is 12 Congress Street, Jersey City Heights, N. J.

E. B. GALLAHER has removed his office from 253 Broadway to 97 Cedar Street, New York City.

W. A. JONES has received the appointment of instructor in mechanical drawing at the Drexel Institute, Philadelphia, Pa.

A. G. KOLLSTEDE is connected with the Chino Valley Beet Sugar Co., Chino, San Bernardino County, Cal., as mechanical engineer.

A. M. LOZIER is in the employ of the Westinghouse, Church, Kerr & Co., 26 Cortlandt Street, New York City.

F. M. OPPERMANN is assistant superintendent of the Pittsburgh Plate Glass Co., Ford City, Pa. Mr. Oppermann returned to the States from Belgium a short time ago.

'95.

PERCY ALLEN is in the employ of the Safety Car Heating and Lighting Co., 160 Broadway, New York City.

D. D. BARNUM is with the Bliss M'f'g Co., Brooklyn, N. Y.

G. EVERETT BRUEN is in the testing department of the Baldwin Locomotive Works, Philadelphia, Pa.

THOS. E. BUTTERFIELD is trying for the degree of civil engineer at the Rennsylaer Polytechnic, Troy, N. Y.

WM. H. CORBETT is with the Garvin Machine Co., Canal and Laight Streets, New York City.

MORGAN E. CRAFT is instructor in shop work in the manual training department of the public schools at Montclair, N. J. He is also assisting Prof. Leeds during the absence of Prof. Manning.

THOS. B. CUMING is in the office of the Worthington Pump Co., 86 Liberty Street, New York City.

RICHARD GUNAGAN is drafting for the Cooke Locomotive and Machine Co., Paterson, N. J.

R. E. HALL has left the employ of Uehling, Steinbart & Co., and is now in the office of superintendent of motive power, B. & O. R. R., Mount Clare, Baltimore, Md.

EDW'D M. HARRISON, JR., is treasurer of the C. C. White Toilet Paper M'f'g Co., 146 Duane Street, New York City.

ARTHUR LENSSEN, JR., is in the employ of the Ansonia Brass and Copper Co., Ansonia, Conn.

F. N. MACVEETY is drafting for A. R. Wolff, '76, Consulting Mechanical Engineer, Fulton Building, New York City.

HOWARD MAXFIELD is employed at the Meadow Shops of the Pa. R. R., Jersey City, N. J.

NESTOR RAMIREZ is with the Westinghouse Electric & M'f'g Co., Pittsburg, Pa.

EDWARD C. SCHMIDT is the mechanical engineer for the Kalbfleisch Chemical Co., Brooklyn, N. Y.

F. R. SMART, JR., is with the East River Gas Co., Ravenswood, L. I., N. Y.

FRED'K K. VREELAND is taking a post-graduate course in electrical engineering at Columbia College, New York City.

F. W. WALKER is with the Edison Illuminating Co., Brooklyn, N. Y.

BOOK NOTICES.

RECENT PUBLICATIONS.

ELEMENTS OF DESCRIPTIVE GEOMETRY. With applications to Isometrical Drawing and Cavalier Projection. By Charles William MacCord, A. M., Sc.D., Professor of Mechanical Drawing in the Stevens Institute of Technology, Hoboken, N. J.

The treatment of descriptive geometry as presented in this book is in some respects different from that found in other books on the subject. These modifications are such as have been suggested by the author's long class-room experience at the Stevens Institute of Technology, extending over a period of more than twenty years. It is believed that, as a text-book, it is especially adapted to the requirements of colleges and technical schools, and that it will be a valuable aid to students studying the subject without an instructor.

The addition of pictorial representations of the elementary problems relating to points, lines and planes, in the abstract, and of the more difficult problems relating to warped surface should materially aid the student, particularly if he is studying without a tutor.

Practical problems are interspersed through the book to illustrate the application of the principles previously given, as well as to show the relation of descriptive geometry to mechanical drawing. This feature of the book, especially, should stimulate the student's interest in the subject. John Wiley & Sons, New York City, publishers. Price, $3.00.

AN ELEMENTARY TEXT-BOOK ON STEAM ENGINES AND BOILERS. By J. H. Kinealy, Professor of Mechanical Engineering, Washington University, St. Louis, Mo. Spon & Chamberlain, 12 Cortlandt street, New York City, publishers.

This book was written for the use of students in universities and colleges, and its adaptation to the requirements of such schools necessarily precluded an exhaustive presentation of the various subjects treated of. The author has, however, aimed to convey to the student in a concise manner an idea of elementary thermodynamics; of the action of the steam in the cylinder of the engine; of the motion of the steam valve; of the differences between the various types of engines and boilers; of the generation of heat by combustion and the conversion of water into steam. The book is illustrated with diagrams and numerous cuts of American types and details of engines and boilers.

PROBLEMS IN THE USE AND ADJUSTMENT OF ENGINEERING INSTRUMENTS. By Walter Loring Webb, C. E., Assistant Professor of Civil Engineering in the University of Pennsylvania.

This is a pocket-book of 64 pages, and is designed to aid in teaching the first elements of instrumental practice to engineering students.

Under each problem is given the "equipment" necessary, general instructions in use of the instruments, and a specimen table for the field notes.

This work, or its equivalent, is considered essential for the efficient instruction of a large number of students in field practice. John Wiley & Sons, New York City, publishers.

INDEX.

PAGE

ABSTRACT of Lecture delivered before the Senior Class. Professor COLEMAN SELLERS, E. D. 249
Alumni Association, List of Members of 101
Alumni Association, Annual Meeting of 325
Alumni Association, Midwinter Meeting 239
ANDERSON, ST. GEORGE M., '94, Test of a 240 H. P. Babcock & Wilcox Boiler with Three Different Coals, for the Determination of Economy 361
An Interesting Well Experience. H. DE B. PARSONS, '84 380
Argon, the New Element. President HENRY MORTON 42
Athletic Notes 242, 344, 423
Automatic Sprinkler Heads, Tests of. Prof. D. S. JACOBUS 45

BOOK Notices. Recent Publications 122, 357
Accessions to the Institute Library 123, 358
Boiler, Test of a 240 H. P. Babcock & Wilcox Boiler, with Three Different Coals, for the Determination of Economy. ST. GEORGE M. ANDERSON, '94, E. J. BURKE, '94 361
BURKE, E. J., Test of a 240 H. P. Babcock & Wilcox Boiler 361

CALORIMETER. On the Berthelot-Mahler Calorimeter for the Calorific Power of Fuels A. M. MAYER 133
Calorimeters. Results of Measurements to Test the Accuracy of Small Calorimeters. D. S. JACOBUS 177
Canals. Railroads and Canals. JOHN STEVENS 288
Change in the Method of Rating Feed Water Heaters 176
Coals. Test of a 240 H. P. Boiler with Three Different Coals, for the Determination of Economy 361
Comparative Test of a Compound Locomotive and a Simple Locomotive on C. R. R. of N. J. RUSSELL E. TAYLOR, '94; CHARLES C. KENYON, '94; E. D. MATHEY, '94 261
Conservation of Energy. HENRY MORTON 307

DAVIS, E. F. C., Late President A. S. M. E. 394
DISCOVERY of Helium in a Terrestrial Mineral (Clevite). HENRY MORTON 226

ELECTRICAL Measurements, Standard for..... 228
Electricity, New Theories as to the Nature of..... 69
Engineering Equivalents. EDWARD J. WILLIS..... 415
Engineering Fallacies. Second paper. HENRY MORTON..... 125
Extracts from the Engineering Press:

An Existing Newcomen Engine.
Concentration and Distillation of H_2O_2.
Drilling Under Forty Feet of Water.
Electricity in Mining.
New Methods with the Indicator.
Recent Researches in the Infra-red Spectrum..... 79
Electricity in Mining.
Master Mechanics' Association Free Scholarships..... 235

FEED Water Heaters, Change in the Method of Rating..... 176

GANZ, ALBERT M., Test of Superheated Steam Plant, by Professor M. SCHROEDER..... 197

INSTITUTE Notes..... 93, 243, 352, 427
Institute Personals..... 97, 245, 353, 431

JACOBUS, D. S., Tests of Automatic Sprinkler Heads..... 45
Results of Measurements to Test the Accuracy of Small Throttling Calorimeters..... 177

KENYON, CHARLES C., Comparative Test of a Compound Locomotive and a Simple Locomotive..... 261

LIST of Members of the Alumni Association..... 101
Locomotive. Comparative Test of a Compound and a Simple Locomotive on C. R. R. of N. J. RUSSELL E. TAYLOR, '94; CHARLES C. KENYON, '94; EDWARD D. MATHEY, '94..... 261

MATHEY, EDWARD D., '94, Comparative Test of a Compound Locomotive and a Simple Locomotive..... 261
Maximum Possible Efficiency of a Galvanic Battery. HENRY MORTON 385
MAYER, A. M., On the Berthelot-Mahler Calorimeter for the Calorific Power of Fuels..... 133
Mechanical Integrators. J. B. WEBB..... 1, 148
MORTON, HENRY, Argon, the New Element..... 42
Engineering Fallacies. Second Paper..... 125
The Conservation of Energy..... 307
The Maximum Possible Efficiency of a Galvanic Battery..... 385

NEW JERSEY the Pioneer in American Industrial Progress..... 414
New Theories as to the Nature of Electricity..... 69

OBITUARY, Johann M. Hansen, '91..... 341
" John Heber Murray, '92..... 342
" Andrew Shiebler, '92..... 422

PAPER. The Chemical and Physical Examination of Paper. THOS. B. STILLMAN..... 169, 282, 389
PARSONS, H. DE B., '84, An Interesting Well Experience..... 380
PARSONS, WILLARD P., '80, Progress in the Cotton Field..... 55
Progress in the Cotton Field. WILLARD P. PARSONS, '80..... 55

RAILROADS and Canals. JOHN STEVENS..... 288, 395
RAMSAY, Professor W., Discovery of Helium in a Terrestrial Mineral (Clevite)..... 226
Results of Measurements to Test the Accuracy of Small Throttling Calorimeters. D. S. JACOBUS..... 177

SCHROEDER, Professor M., Test of a Superheated Steam Plant..... 197
SELLERS, COLEMAN, Lecture to the Senior Class..... 249
SHIEBLER, ANDREW, '92, Obituary..... 422
Standards for Electrical Measurements..... 228
STEVENS, JOHN, Railroads and Canals..... 288, 395
STILLMAN, THOMAS B., The Chemical and Physical Examination of Paper..... 169, 282, 389
Superheated Steam Plant, Test of, by Prof. M. SCHROEDER; Translated by A. M. GANZ, '95..... 197

TAYLOR, RUSSELL F., '94, Comparative Test of a Compound Locomotive and a Simple Locomotive..... 261
Test of a Superheated Steam Plant, by Prof. M. SCHROEDER; Translated by A. F. GANZ, '95 197
The Chemical and Physical Examination of Paper. THOS. B. STILLMAN..... 169, 282, 389

UNIVERSITIES. DE V. WOOD..... 51

WEBB, J. BURKITT, Mechanical Integrators..... 1, 148
WOOD, DE VOLSEN, Universities..... 51
WILLIS, EDWARD J., '88, Energy Equivalents..... 415

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Earth. Mean Density of the —. Professor POYNTINGS. Am. Jour. of Sc., Vol. 48, No. 288; Nature, Oct. 4, 1894.
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Electric Lighting of Buildings. Suggestions in Preparing Specifications for the —. NELSON W. PERRY. Eng. Record, Vol. 31, No. 2.
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—— **Direct from Fuel.** A reply to Dr. Borcher's article in Elec. World of Dec. 8, 1894. C. J. REED. Elec. World, Vol. 24, No. 25.

Electro-Dynamic Machinery. A series of papers by E. J. HOUSTON and A. E. KENNELLY in the Elec. World, Vol. 24, No. 24. This subject includes not only the apparatus by which mechanical energy is converted into electrical energy, but also the translating apparatus, the transmission circuits, and the apparatus required for the measurement of electrical energy.

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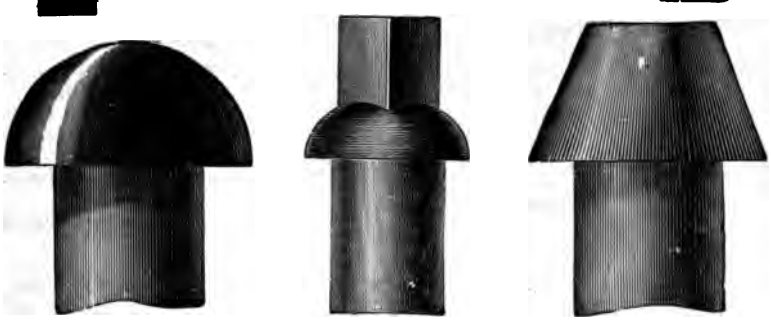

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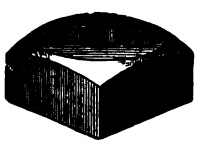

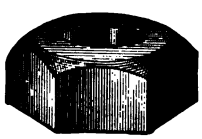

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—— **Shops.** Compressed Air in — —. F. M. WILDER, C. E. Railroad Gazette, Vol. 27, No. 1.
Railway. Notes on the Brooklyn Elevated —. A. A. STUART. Jour. Ass'n Eng. Soc., Vol. 8, No. 11.
——. The Wyoming Valley Interurban —. St. Ry. Jour., Vol. 10, No. 12.
—— **Companies** and their Employees. O. D. ASHLEY. Railway Age, Vol. 19, No. 50.
—— **Power Stations.** A series of papers. GEORGE T. HANCHETT. Elec. World, Vol. 24, No. 22.
—— **System.** The Meigs Elevated — —. Engineer (Lon.), Vol 78, No. 2,034.
Railways. A Closed Conduit System for Electrical — at Washington, D. C. Engineer, (Lon.), Vol. 78, No. 2,032.
——. The Street — of St. Louis. WM. H. BRYAN, M. E. Eng. Mag., Vol. 8, No. 3.
Rapid Transit in New York City. Railroad Gazette, Vol. 27, No. 1.
Reactance. A Definition of —. C. P. STEINMETZ and F. BEDELL. Elec. World, Vol. 24, No. 22; A. BLONDEL. Elec. World, Vol. 25, No. 1.
Relay. A New Form of Polarized —. T. H. LLOYD. Electrician, Vol. 34, No. 865.
Resistance of Materials. Elasticity and — — —. GUS. C. HENNING. Am. Mach., Vol. 17, No. 52.
Retorts. Inclined — at the Leigh (Eng.) Gas Works. Am. Gas Light Jour., Vol. 61, No. 25.
Review for Year 1894, giving from three to six columns for each of the following scientific departments, and showing the principal lines of advance in each: Mechanical, Electrical, Civil, and Sanitary Engineering, Metallurgy, Harbors, Waterways, War Material and Gas Supply. Engineer, (Lon.), Vol. 79, No. 2,036.
Roof. A Tile — for an Electric Lighting Plant. Railroad Gazette, Vol. 27, No. 1.
——. An Iron Residence — for the House of John Jacob Astor in New York City. Eng. Record, Vol. 31, No. 5.
—— **Work.** The Calculation of Hip and Valley Angles in — —. C. A. P. TURNER, C. E. Eng. News & Am. Ry. Jour., Vol. 32, No. 51.
Roofs and Iron Buildings. Fowler's Specifications for — — — —. Eng. Record, Vol. 31, No. 4.
Rope Driving. Part XIII. A series of papers by J. J. FLATHER. Elec. World, Vol. 24, No. 26.

S.

Salts. Solution of — in Organic Liquids. C. E. LINEBARGER. Am. Jour. of Sc., Vol. 49, No. 289.
School Buildings. Proper Heating and Ventilation of — —. R. R. WADE. Heating & Vent., Vol. 4, No. 12.
Scrap Pile. Some Lessons of the — —. J. N. BARR. Railroad Gazette, Vol. 26, No. 49.
Sea Wall. Construction of a — at Fort Taylor, Key West, Fla. Lieut.-Col. JARED A. SMITH. Jour. Ass'n Eng. Soc., Vol. 8, No. 11.
Sewer Construction in Boston, Mass. Eng. Record, Vol. 31, No. 4.
Ship. Electricity on Board . ALFRED H. GIBBINGS. Sc. Am. Sup., Vol. 39, No. 992.
Ships' Turrets. The Application of Electricity to Sinking — —. A series of papers in Engineering, Vol. 59, No. 1,514 *et seq.*
Shop Methods. Modern — —. F. H. COLVIN. Machinery, Vol. 1, No. 5.
Shops. The Flint & Pere Marquette — and Passenger Station at Saginaw, E. S. Michigan. Am. Eng. & R. R. Jour., Vol. 69, No. 1.

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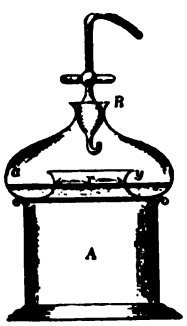

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Switchboard. The Evolution of a —. ARTHUR VAUGHN ABBOTT, C. E. Uni. Wis. Bul., Vol. 1, No. 4.

T.

Tar Still. Lennard Continuous — —. Am. Gas Light Jour., Vol. 61, No. 27.
Telegraphic Blunders. Cost of — —. Electricity, Vol. 7, No. 24.
Telephone. The —. NELSON W. PERRY. Electricity, Vol. 8, No. 1.
—— **Exchange System.** Callender Automatic — — —. Elec. Eng., Vol. 18, No. 349.
—— **Patent Situation.** Elec. Eng., Vol. 18, No. 347; Elec. World, Vol. 24, No. 26.
—— **Troubles.** Peculiar — — Caused by Alternating Currents. E. W. MIX. Electrician, Vol. 34, No. 867.
Telephony. Long Distance —. F. W. DUNBAR. Elec. World, Vol. 25, No. 2.
Telescopes. Equatorial Stand for Small —. GEO. M. HOPKINS. Sc. Am., Vol. 71, No. 26.
Temperature. Relation of Air Volume to —. WALTER B. SNOW. Heating and Vent., Vol. 12, No. 4.
Temperatures. Apparatus for Experimenting with —. Sc. Am. Sup., Vol. 38, No. 990.
Thermodynamics. Graphic —. RENI DE SAUSSURE. Am. Jour. of Sc., Vol. 49, No. 289.
Tickets. Railroad Employes' — in England. Railroad Gazette, Vol. 27, No. 1.
Torpedo Boats for Cruiser "Maine." Sc. Am., Vol. 72, No. 1.
Torpedoes. Naval — and their Manufacture. WARREN E. WILLIS. Machinery, Vol. 1, No. 4.
Track. Machine for Trimming and Weeding Railroad —. Railroad Gazette, Vol. 27, No. 2.
Traction Co. The System of the People's — of Philadelphia. St. Ry. Jour., Vol. 11, No. 1.
Train Lighting by Electricity on Danish Railways. Am. Gas Light Jour., Vol. 62, No. 2.
Tramways. Notes on Electric — in the United States and Canada. H. D. WILKINSON. Elec. Eng., Vol. 18, No. 344.
— —. Present and Prospective Development of Electric —. C. J. FIELD. Trans. A. S. M. E., Vol. 18, No. 619.
Transformer. Principles of — Design. Elec. World, Vol. 24, No. 23.
—— **Testing.** EUSTACE OXLEY. Elec. World, Vol. 24, No. 23.
Transformers. Increase of Open Circuit Loss in — with Time. G. W. PARTRIDGE. Electrician, Vol. 34, No. 864; Dr. J. A. FLEMING. Electrician, Vol. 34, No. 865.
Transmission. Calculation of a Compressed Air — when the Subsidiary Losses of Energy are taken into account. Prof. UNWIN. Eng. Mech., No. 277.
— —. Compressed Air — with Electrically Heated Compressed Air Engines. T. J. FAY. Elec. Eng., Vol. 18, No. 347.
Trolley System. An Important Legal Decision by Judge BRADY in Massachusetts Sustaining the — — —. St. Ry. Jour., Vol. 10, No. 12.
Trolley Wires. The Sag in — —. E. A. MERRILL. Elec. World, Vol. 24, No. 22.
Trucks. Arch Bars of Freight Car —. R. R. Car Jour., Vol. 4, No. 12.
Tubular Articles. Manufacture of — —. Iron Age, Vol. 54, No. 25.
Tunnel. Enlarging a — in Soft Ground. Eng. News and Am. Ry. Jour., Vol. 32, No. 49.
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——. The Simplon. Engineer, (Lon.), Vol. 79, No. 2037. W. G. TRIEST, JR.; Railroad Gazette, Vol. 26, No. 52.

W.

Water Measurement by Miners' Inches. Industry, No. 77.
Water Meter. A New Current — — and a New Method of Rating Current Meters for Velocities of Water in Shallow Rivers, Canals, etc. W. G. PRICE, U. S. Assistant Eng. Eng. News & Am. Ry. Jour., Vol. 33, No. 2.
Water Pipes. Analysis of Electrolyzed — —. JOSEPH RIGGE. Am. Gas Light Jour., Vol. 61, No 23.
Waterways vs. Railways. Railway Age, Vol. 24, No. 52.
Wells for Town Supplies. HENRY DAVEY. Cassier's, Vol. 7, No. 3.
Welsbach Burners. Combustion Products of — —. Prog. Age, Vol. 12, No. 23.
Wheel. The Gigantic — at Earle's Court. Engineer, (Lon.), Vol. 78, No. 2034.
——. The Perfect —. St. Ry. Jour., Vol. 11, No. 1.
—— **Flanges.** Street Railway — —. St. Ry. Jour., Vol. 11, No. 1.
Wheels. Action of — on Curves. St. Ry. Jour., Vol. 11, No. 1.
Wind. Practical Measurement of the Velocity of the —. Sc. Am. Sup., Vol. 39, No. 992.
—— **Bracing** for High Buildings. Eng. Record, Vol. 31, No. 5.
—— **Pressure.** Am. Gas Light Jour., Vol. 61, No. 23.; Eng. Mech., No. 277.
Wire Losses. Over-Compounding of Dynamos and Regulation of P. D. in Multiple Arc Circuits. E. P. ROBERTS. Elec. World, Vol. 24, No. 23.
Wiring. Conduit —. A. NOLL. Elec. Eng., Vol. 18, No. 348.

Z.

Zero. Search for the Absolute —. HENRY J. W. DAM. Prog. Age., Vol. 12, No. 24.

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INDEX.

A.

Abrasive Material. Garnet as an —. F. C. HOOPER. S. M. Q., Vol. 16, No. 2.
Accumulators. Electric - - under Pressure. S. A. S., Vol. 39, No. 995.
——. Schaeffer-Heinemann —. Elec'y, Vol. 8, No. 7. E. & M. J., Vol., 59, No. 7.
Acetylene. Sc. Am., Vol 72, No. 8.
——. The Commercial Synthesis of Illuminating Hydrocarbons. Prof. V. B. LEWES. S. A. S., Vol. 39, No. 998.
—— and the Gas Industries. M. H. HUMPHREYS. A. G. L. J., Vol. 62, No. 8.
—— **Apparatus.** T. O. SLOANE. Sc. Am., Vol. 72, No. 13.
—— as an Illuminant. Eng'r (Lon.), Vol. 79, No. 2038.
Air Brake. Evolution of the - -. PAUL SYNNESTVEDT. R. E. & M., Vol. 11, No. 3.
Alloys. The Composition and Constitution of certain - -. Ternary, Quinary, Septenary, Octenary and Nonary Alloys. Dr. C. R. A. WRIGHT. S. A. S., Vol. 39, Nos. 999 and 1,000.
Alternating Currents. Prof. E. J. HOUSTON & A. E. KENNELLY. El. Eng., Vol. 19, Nos. 351 and 352.
—— ——. Some Experiments with —. A. GRIFFITHS. Ph. Mag., Vol. 39, No. 298.
Alternating Current Curves. On the Delineation of when the Alternator is not Accessible. Dr. J. A. FLEMING. El. Eng., Vol. 19, No. 357; Elec'n, Vol. 34, Nos. 873 and 875.
——— ——. Method of Obtaining - -. L. DUNCAN. El. Eng., Vol. 19, No. 356.
Alternating Current Transformers. Core Losses in -. E. WILSON. Elec'n, Vol. 34, Nos. 873 and 875.
Ammonia. Method of Determining — in Ammonia Chloride. C. B. DUDLEY and F. N. PEASE, chemists for P. R. R. Am. Eng., Vol. 69, No. 1.
Aniline. The Influence of Temperature on the Specific Heat of —. H. E. GRIFFITHS. Ph. Mag., Vol. 39, No. 236.
Animal as a Prime Mover. J. F. I., Vol. 139, Nos. 829 and 830.
Apprentices. Training - in Test Dep't Baldwin Locomotive Works. E. A. CUSTER. Lo. Eng., Vol. 8, No. 2.
Arc Lamps. Arc Carbons and the Rating of —. L. B. MARKS. El. W'ld, Vol. 25, No. 9.
—— —— . The Candle Power of —. El. W'ld, Vol. 25, No. 10.
Arc Light. The Influence of the Carbons on the Candle Power of the —. W. M. STINE, D. Sc. El. W'ld, Vol. 25, No. 8.
Argon. Eng. (Lon.), Vol. 79, No. 2041. G. J. STONEY. S. A. S., Vol. 39, No. 1003; Ch. News, Vol. 71, Nos. 1837 and 1838. Pres. HENRY MORTON. St. Ind., Vol. 12, No. 1.
——. Attempts to make - enter into Chemical Compound. Ch. News, Vol. 71, No. 1844.
——. How to Prepare - - on a Large Scale. B. BRAUNER. Ch. News, Vol. 71, No. 1837.
——. Liquefaction and Solidification of - . Ch. News, Vol. 71, No. 1834; S. A. S., Vol. 39, No. 1002; Nat., Vol. 51, No. 1319.
——. Previous Anticipations of - Before Its Discovery. Lord RAYLEIGH and Prof. RAMSAY. Ch. News, Vol. 71, No. 1843.
——. Spectra of . H. F. NEWELL. Ch. News, Vol. 71, No. 1841; Nat., Vol. 51, No. 1319; S. A. S., Vol. 39, No. 1002.

Argon, the New Constituent of the Atmosphere. Considered under the following heads: I. Density of nitrogen from various sources. II. Reasons for suspecting a hitherto undiscovered constituent in air. III. Methods for causing free nitrogen to combine. IV. Early experiments on sparking nitrogen with oxygen in presence of alkali. V. Early experiments on withdrawal of nitrogen from air by means of red-hot magnesium. VI. Proof of the presence of argon in air by means of atmolysis. VII. Negative experiments to prove that argon is not derived from nitrogen from chemical sources. S. A. S., Vol. 39, Nos. 1000–1–2.
— and the Periodic System. Nat., Vol. 51, No. 1325.
Armatures. Method of Determining the Eddy Current and Hysteresis Losses in Direct Current —. A. W. K. PIERCE. Elec'y, Vol. 8, No. 9.
— . Reversible Regenerative and Short-Air-Space Dynamos. W. B. SAYERS. Elec'n, Vol. 34, No. 877; Eng'g, Vol. 59, No. 1523.
Armor. Face Hardened —. Capt. W. F. SAMPSON. P. U. S. N. I., Vol. 20, No. 4.
Armor Plate. The Electric Annealing of —. El. Eng., Vol. 19, No. 357.
Axles. Steel —. L. R. POMEROY. Eng. News, Vol. 33, No. 5.

B.

Ball, Bolt and Screw Forging Machines and Ball Bearings. Eng'r (Lon.), Vol. 79, No. 2043.
Batteries. Dry —. L. K. BÖHM. El. W'ld, Vol. 25, No. 6.
Battery. The Walker-Wilkins Patent Non-Polarizing Voltaic —. W. R. COOPER, M. A. Elec'n, Vol. 34, No. 872.
Bicycle. Complete account of the making of a —. Eng'g, Vol. 59, No. 1525.
Blast Furnace. Thwait's —. Pr. Age, Vol. 13, No. 3.
Block Signalling. W. H. ELLIOTT. Lo. Eng., Vol. 8, No. 3.
Blowing Engines and Machinery; their Construction and Design. A. VON IHERLING. Eng. Mech., No. 279.
Boats. Steam Life —. Eng'g, Vol. 59, No. 1516.
Bogie. History of the four-wheeled —. C. E. STRETTON, C. E. S. A. S., Vol. 39, No. 996.
Boiler. A 2,000-year-old —. N. C. & L. B., Vol. 26, No. 2.
— and **Engine**. Schmidt's Superheated Steam —. Am. Eng., Vol. 69, No. 2.
— **Covering**. E. A. WILLIAMS. Ry. Age, Vol. 20, No. 7.
— **Efficiency**. Locomotive —. R. R. G., Vol. 27, No. 4.
— **Explosion**. The Hoxton —. Eng'g, Vol. 59, No. 1521.
— **Explosions**. W. H. FOWLER. Eng'r (Am.), Vol. 29, No. 5.
— **Heating Surface**. C. SKARSTEDT. Am. Mach., Vol. 18, No. 11.
— **Making**. Modern —. W. O. WEBBER. Cassier's, Vol. 7, No. 5.
— . The Elements of —. C. E. FOURNESS. Lo. Eng., Vol. 8, No. 2.
— **Scale**. A Device for Feeding Resolvent —. W. H. WAKEMAN. Mach., Vol. 1, No. 6.
— **Shells**. Machinery for Drilling Locomotive —. R. E. & M., Vol. 11, No. 3.
— **Tests**. Manchester Steam Users Ass'n. Eng'g, Vol. 59, No. 1525.
— **Work**. Double Radial Drill for —. R. E. & M., Vol. 11, No. 3.
Boilers. On Results of Evaporative Tests on Land —. G. C. THOMSON. Eng'g, Vol. 59, Nos. 1517 19 20.
— . The Deterioration of Locomotive and Marine — due to Expansion, and Means of Lessening the Same. Herr LENTZ. Am. Eng., Vol. 69, No. 3.
— . Water Tube — and Their Application to War Vessels. J. NASTOUPIL. Am. Eng., Vol. 68, No. 12; Vol. 69, Nos. 1 and 2.
— —. Water Tube — for Marine Purposes. W. F. DURAND. S. J. E.
— for **Central or Power Stations**. F. SCHEFFLER. Mach., Vol. 1, No. 6.
Borcher's Cell. Elec'n, Vol. 34, No. 875.

Breakwaters. Stability of Crib —. Eng. Rec., Vol. 31, No. 13.
Brick. Vitrified —. T. W. GIBSON. S. M. Q., Vol. 16, No. 2.
Bridge. Foot Bridge of Old Rails, Showing Details of Construction. R. R. G., Vol. 27, No. 8.
——. Hudson River —. Eng. Rec., Vol. 31, No. 15.
——. New — Over the East River at Blackwell's Island, New York. Sc. Am., Vol. 72, No. 8.
——. Sixteenth Street Bascule —, Milwaukee. Eng. Rec., Vol. 31, No. 15.
——. Specifications for a Suspension — Over the Hudson River at New York. Eng. News, Vol. 33, No. 10.
——. Van Buren Street Rolling Lift —. Eng. Rec., Vol. 31, Nos. 12 & 14; R. R. G., Vol. 27, No. 7; Eng. News, Vol. 33, No. 8.
—— **Specifications.** Hudson River —. R. R. G., Vol. 27, No. 10.
—— **Works' Rules for Drafting-Room Work.** C. H. WRIGHT. Eng. News, Vol. 33, No. 6.
Bridges. Tests of Steel for —. Eng. News, Vol. 33, No. 9.
——. Thames —. Eng'g, Vol. 59, Nos. 1516–1525.
Bromide Prints. The Permanence of —. An Improved Developer. Sc. Am., Vol. 72, No. 4.
Bromovalerianic Acid. J. G. SPENZER. A. J. S., Vol. 49, No. 290.
Brush Electric Co. El. Eng., Vol. 19, No. 355.
Building Stones. Comparative Tests of —. C. A. RAYMOND. Eng. News, Vol. 33, No. 13.

C.

Calcium Carbide. A new product of the Electrical Furnace. J. F. I., Vol. 34, No. 871.
Calorimetric Determinations. Graphical Method for Correcting —. S. J. E.
Car Illumination. Gas for Electric —. S. R. J., Vol. 11, No. 2.
—— **Ventilation.** Dr. G. P. CONN. H. & V., Vol. 5, No. 4.
Carbon Vapor. The Efficiency of — in Coal Gas and other Hydro-carbon Flames. L. T. WRIGHT. A. G. L. J., Vol. 62, No. 11.
Carbons and Rating of Arc Carbons. F. B. MARKS. El. Eng., Vol. 19, No. 356.
Case School of Applied Science. El. Eng., Vol. 19, No. 355.
Cement Mortar. Specifications for Portland —. F. H. LEWIS. P. E. C. P., Vol. 2, No. 5.
—— ——. Stamp Sand in —. E. KIDWELL. E. & M. J., Vol. 59, No. 8.
Central Station Economy. Elec'y, Vol. 8, No. 6.
Central Stations. Coal Consumption in — E. A. MERRIL. El. W'ld, Vol. 25, No. 8.
—— ——. Storage of Energy Essential to Economy of Working in —. N. W. PERRY. Elec'y, Vol. 8, No. 7.
Chemistry. On the Absorption Spectra of Dilute Solutions. T. EWAN, B. S. P. R. S., Vol. 57, No. 341.
Chimney. Factory— Struck by Lightning. Sc. Am., Vol. 72, No. 9.
——. Straightening a Leaning —. J. C. PLATT. Cassier's, Vol. 7, No. 4.
Chimneys. F. T. HODGSON. A. G. L. J., Vol. 62, No. 4.
——. Draft Power of —. W. B. L. VANE. Mach., Vol. 1, No. 6.: E. D. MEIER. Pow., Vol. 15, No. 2.
Chloride. Method of Determining — in Ammonia Chloride. C. B. DUDLEY. and F. N. Pease, Chemists for P. R. R. Am. Eng., Vol. 69, No. 1.
Chuck. A New Emery Cylinder —. Am. Mach., Vol. 18, No. 8.
Civil Engineers. The Institution of — (Lon.). Eng. Rec. Vol. 31, No. 11.
Coal. Economy in the Use of — by Railroads. S. P. BUSH. N. C. & L. B. Vol. 26, No. 3.
—— Consumption in Central Stations. E. A. MERRILL. El. W'ld, Vol. 25, No. 8.

Coal Dust. Friedeberg Apparatus for Burning —. Am. Eng., Vol. 69, No. 3.: E. & M. J., Vol. 59, No. 6.: S. A. S., Vol. 39, No. 995.
—— Handling and Ashes at the Brooklyn Station of the Edison Electrical Illuminating Co. El. Eng., Vol. 19, No. 355.
Cold Storage and Cold Rooms from Compressed Air. S. A. S., Vol. 39, No. 999.
Color Test. Mechanical — —. M. BENJAMIN, Ph. D. Sc. Am., Vol. 72, No. 8.
Combustion. Complete —. Different Coals. J. C. MCMYNN. A. G. L. J., Vol. 62, No. 8.
Combustions. On —. T. B. P. WARREN. Ch. News., Vol. 71, No. 1837.
Compressed Air. The Use of —. C. A. BENNETT. E. & M. J., Vol. 59, No. 5.
Concrete. Materials for Hydraulic — and Best Methods of Mixing. C. H. PLATT, C. E. Eng. News, Vol. 33, No. 9.
——. Practical Notes on — —. S. B. NEWBERRY. S. A. S., Vol. 30, No. 997.
Condensers. Surface, Evaporative and Dry Air —. E. T. CARTER. Elec'n, Vol. 34, No. 876 : Jet and Ejector —. Elec'n, Vol. 34, No. 870.
Construction of a Great Building. F. H. KIMBALL. Eng. Mag., Vol. 8, No. 5.
—— **Work.** Engineering of Architectural and Building —. Eng. Rec., Vol. 31, No. 9.
—— ——. Use of Steel in Large Buildings. C. T. PURDY. Eng. Rec., Vol. 31, No. 12.
Corliss Engine. Erection of a —. A. S. MANN. Pow., Vol. 15, No. 3.
—— **Valve Motion.** Diagram of a —. S. H. BUNNELL. Am. Mach., Vol. 18, No. 11.
Correspondence School of Technology. Prof. Roberts and the —. El. Eng., Vol. 19, No. 355.
Corrosion of Metal. The Effect of Stress on the —. P. U. S. N. I., Vol. 20, No. 4.
Crankpin. Position of —. R. TOLLINGER. Pr. Age, Vol. 13, No 5.
Cruiser "Maine." The U. S. Armored — —. Am. Eng., Vol. 69, No. 3.
Curve Tracing. Practical — for Graphical Calculation. A. H. SHIELD. Eng'r (Lon.), Vol. 79, No. 2042.
Cylinder Condensation. W. H. BOOTH. Am. Mach., Vol. 18, No. 6.: T. ROSE. I. & R., Vol. 8, No. 2.
Cylinders. Proportion of Compound Engine — —. Eng. Rec., Vol. 31, No. 10.

D.

Dams. American Types of Movable — and Their Development. Lieut. H. M. CHITTENDEN. Eng. News., Vol. 33, No. 6.
—— **and Weirs.** The Sandy Lake —. Eng. Rec., Vol. 31, No 10.
Designing. Hints on — —. An Inside Facing Tool. W. H. STEDMAN. Am. Mach., Vol. 18, No. 5.
Draining Machinery. Ind., No. 79.
—— **of the Zuider Zee.** S. A. S., Vol. 30, No. 998.
Drill. Dixon Hand —. E. & M. J., Vol. 59, No. 6.
——. Notes on the Electric Percussive —. A. T. SNELL. Elec'n, Vol. 34, No. 877.
Dry Docks. Puget Sound —. (With inset.) Eng. News, Vol. 33, Vo. 4.
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